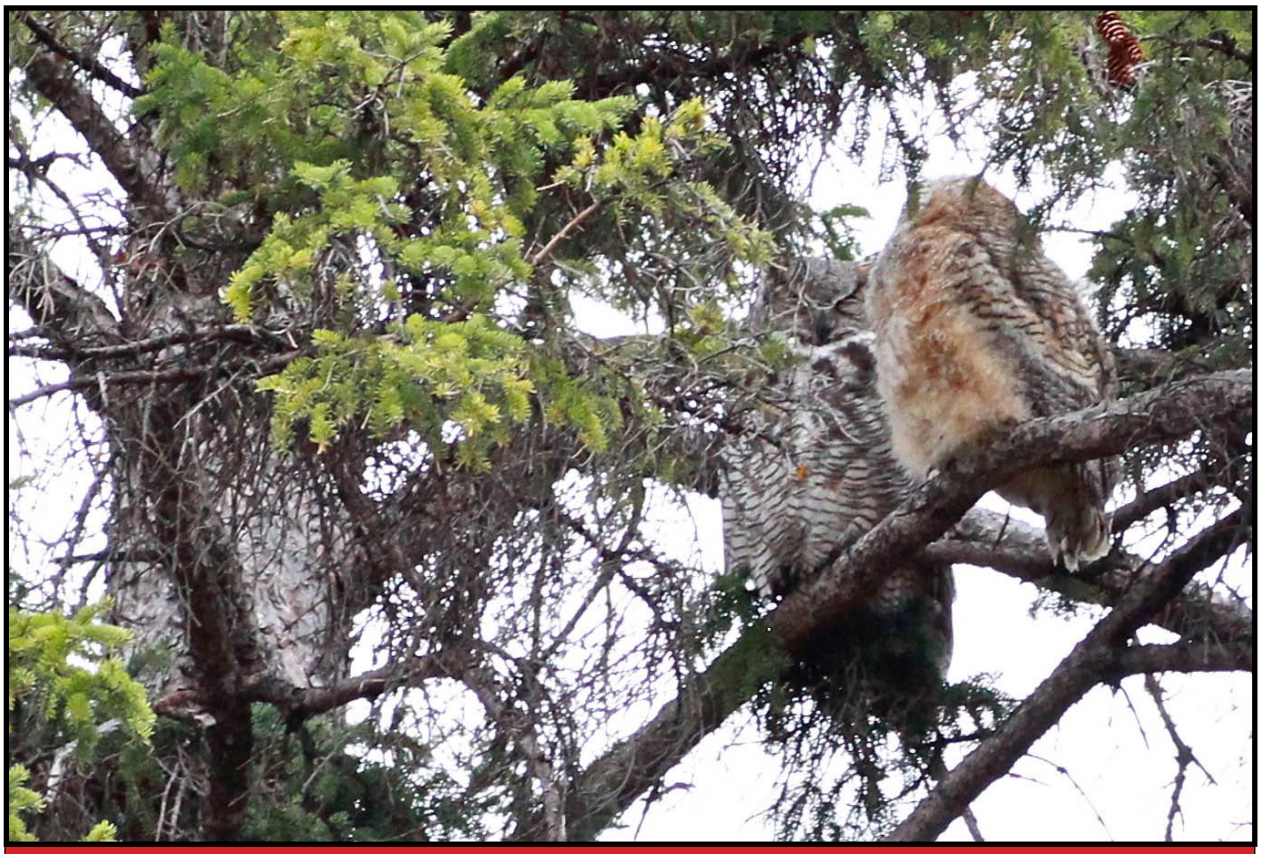


American Crows are food for Great Horned Owls – 17 May 2013 in **Winnipeg**

Population Characteristics

7

Before any population of birds can be understood or subjugated (depending on our goal), its members should be identified according to age and sex. From there, the string of forces that allows an avian population to increase, remain stable, or decease, ought to be examined. The breeding season, already touched upon, serves to regenerate the population. Against this multiplication, other pressures act upon birds to subtract their numbers through death, disease, injuries and in more subtle ways, by the actions of non-lethal parasites and bacteria.

Feathers from Victorian duster
Dyed by the fluids of darkest night
Orange steel beaks
Delivered with bone rattling whams

They look at you with one eye
Only need half of me they say
To deal with you, wingless biped

– David Scott 2010

Plumage

At a distance the American Crow's adult plumage resembles an all black painting by the American artist Ad Reinhardt (1913–1967). A crow, by its size, outline, and simple coloration, is obvious to other species and other crows. It has a sure presence. The belly is as black as the back, the tail as the head. But up close, in bright sunlight, the highlights and feathery outlines reveal their layered intricacies.

A black plumage absorbs heat from infrared wavelengths of sunlight. Yet, even in the dry Great Basin of the American southwest, many

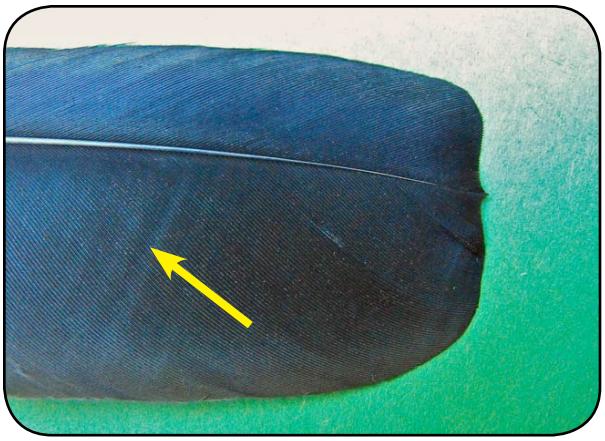
AMERICAN CROW pants and lowers its wings to reduce its temperature on a sunny day

birds have a dark plumage. Against the wall of heat, ground-foraging birds search for their food early and late in the day. At other times, they reduce their activity and seek shade, even shade cast by utility poles or standing cattle. Crows, with their mandibles open (gaping), expose their moist mouths, which increases evaporation and heat loss. They may temporarily elevate their breathing rate to a panting level [41r].

Ageing crows

To age an American Crow externally, one has to examine their feathers for wear and color, and the lengths of various body parts, all of which should be used in concert to arrive at a reliable age. Crows are easily separated in two categories – juveniles and older birds. Emlen listed 6 differences in primary flight feathers and tail feathers that distinguish a juvenile (hatch year, HY bird) from an adult crow [e35] –

(1) Tail feather tips of juveniles show more wear than those of adults. Growth bars (stress-related streaks across feathers) are more common in



Tip of an adult crow's tail feather molted the first week in August, 2011 in Winnipeg; 4.3 cm wide with faint light and dark growth bars (arrow)

Tip of a ragged juvenile tail feather 3 cm wide was molted in early in August 2011 from a yearling crow that took on the darker adult colors during its first complete molt in **Winnipeg**

feathers of birds during their first calendar or hatch year

(2) Flight feathers of HY birds have less black pigmentation than those of adults. The open wings have a dark brownish look

(3) The ventral side of the rachis of the outer wing feathers is whitish most of its length in HY birds. In adults, only the ventral furrow in the rachis is whitish between the dark ridges to within 2 cm of the feather's tip

(4) The shape of tail feathers differ. In HY birds the tips are bluntly rounded, while in adults they are flatter. This is a quick, reliable way to differentiate the two age groups

(5) The overall shape of the tail in HY birds is flatter (squarish) than the more rounded shape for adult birds. In HY birds, the length differences between the central and the next to outer tail feathers is 5–6 mm, compared to about 12 mm for the adults of both sexes, which produces the rounded outer shape of an adult's tail

(6) Although there is overlap, generally, the mid-winter average wing chord length of male HY birds is 1.3 cm shorter than adult male crows. Female HY wing chords average 1.2–1.6 cm shorter than adult females at the same location

For the Fish Crow, the average tail and wing lengths were the two most useful characteristics to distinguish juveniles from adults [b56]. At Ithaca **New York**, the estimated ages of older nestlings of American Crows when banded at 24–30 days were **"**based on the two significant regression lines for tail length and 7th primary length versus age for known-aged birds banded in this population over the previous 15 years**"** [h66].

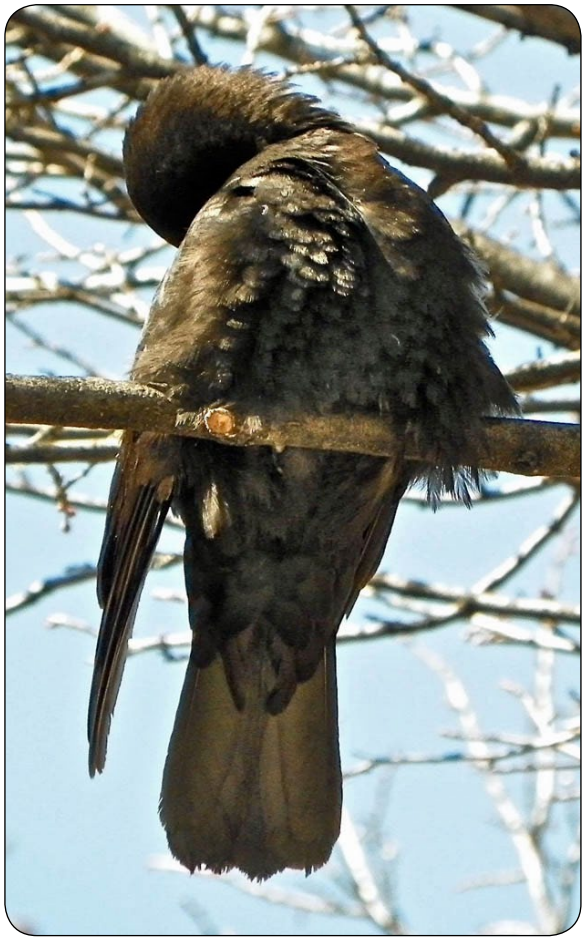
AMERICAN CROW A juvenile about 6 months old found dead in Kent County, **Ontario**. The ragged tail feather tips and brownish cast to the worn primaries help to age this bird

Molting

From a closer look at feather replacement, it was not a 2-step process as previously described, but an intermittent and well-timed process. The loss of an old, worn feather is brought about by the initiation of growth of the new feather which pushes the old one out of the follicle. "The outer layer of the calamus of the old feather and the sheath of the new feather are apparently continuous. The physical connection is still present when growth is renewed in a papilla which has been dormant 10 months" w31.

A few systems to describe molting and the resulting plumages are available. As far as I am concerned, they are a source of much confusion due to their names and the lack of timing given in their descriptions. Ornithologists tried to cover all the birds with one system, which was difficult. I will try to explain molts by the American Crow as simply as possible. Ageing of birds is according to our annual calendar, (adding even more confusion), and does not coincide with the true age of a crow according to the crow's calendar. Let's begin with the hatching of a crow's egg –

A brownish cast to the main wing feathers is a good indication of a yearling crow on the 20th of April before the molt of the large juvenile feathers gets underway for the first time in the bird's life



A Basswood branch is an ideal perch for a young yearling American Crow to preen on 20 April. Note the brownish cast, and ragged, worn tips of the 12 juvenile tail feathers that will soon be shed

(1) A nestling is dressed in a partial downy plumage. The very young crow is mostly naked
(2) As it grows in the nest, the natal down is replaced by the juvenile plumage before it fledges at 30–35 days post hatching
(3) The juvenile dress undergoes a partial molt of the body and smaller feathers over the first summer. A crow enters its first winter with new and old feathers
(4) In our next calendar year (AHY), the FIRST complete molt of feathers occurs over the second summer as the old, well-worn juvenile wing and tail feathers are replaced along with all of the other feathers. The yearling crow enters its second winter in a totally new, shiny dark plumage
(5) In its plumage at the start of its second spring, the yearling now looks like an adult, and enjoys its SECOND complete annual molt into its adult plumage over its third summer, by the crow's

calendar

(6) From now on, the crow has an annual complete molt each summer and wears its striking black, glossy breeding plumage everywhere

With this sketch in hand, I can now provide more details. Remember, there are many gaps in our knowledge of the molting processes of many birds, including the American Crow. By comparison, nesting and migration are much more studied and understood. The strategy and physiology of molting are hardly realized. It has been suggested that birds may be able to detect turbulence due to worn wing feathers, and this may somehow trigger a response to begin molting [73b].

In the early 1960s, the British Trust for Ornithology began a molt-card program that has added much to our knowledge. Here in the New World, molting is not very sexy, so little work on it has been published. Bird banders can contribute, if they take the time and have an interest in feather development. Web initiatives, like eBird with 70,000 birders, are changing the way we communicate and learn about birds.

Even when rearing captive crows and collecting and identifying the sequence of molted feathers, the process of captivity may alter the timing of the molting process. As well, molting patterns are influenced by the habitat of a bird, diet, its distance of migration and breeding cycle [05p].

All of the systems developed to describe the molts and plumages of birds have been criticized. The first descriptive system from 1900 by Dwight was based on two main plumages [d81] –

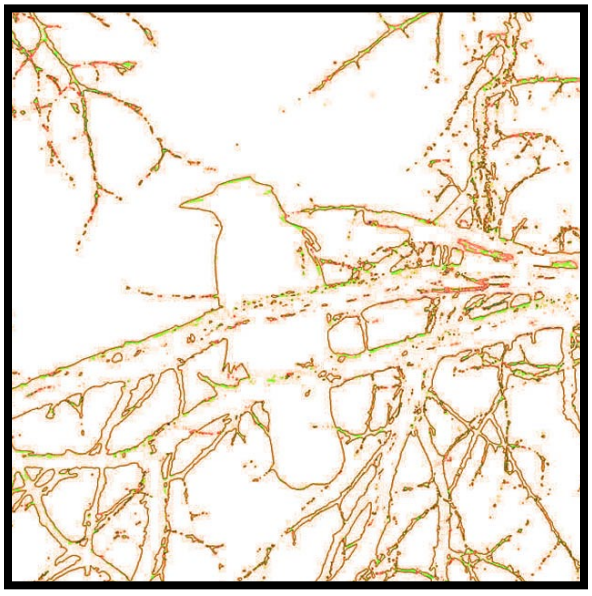
(1) winter
(2) breeding (or nuptial)

This system runs into problems with birds that breed in the Southern Hemisphere, and winter in the Northern Hemisphere, and birds that do not breed until two or more years of age, like the American Crow.

Perhaps the most elegant and simple system resulted from an improvement of the initial attempt. It described plumages and the subsequent molts [a24].

(a) Downy plumages
(b) Pennaceous plumages (vaned feathers)
(c) Adult plumage

This system is well suited to the American Crow. The hatchling is born with a partial downy plumage. The nestling undergoes a postnatal molt into the juvenile plumage (vaned feathers) while still in the nest. If more than one molt occurs,



the adjective "second," etc, is used. If sexual dimorphism of plumages occurs, the term female or male is applied. Other descriptive phrases are listed in the article.

Names for molts were presented by Humphrey and Parkes in 1959. A molt beginning with pre- was named for the incoming plumage. For example, the Prebasic molt produced the basic plumage [60h]. The Prejuvenile molt produced a juvenile plumage [w31]. In the H-P system a molt is "a generation of feathers attained by a molt, and the color of the feathers is not relevant" [47h].

The molting sequence of a group of captive or wild American Crows has not been studied. We rely on other corvids for some information. For example, in the 1970s, detailed data on the molting of live Scrub Jays and Blue Jays were gathered at the Archbold Biological Station in south central **Florida**. Both species of jays were common permanent residents. There were slight differences in the pattern of molting between these two corvids [b29]. Briefly –

First prebasic molt – all the body feathers are replaced. A few secondaries, 7–10, were also replaced, as were the central pair of tail feathers. Blue Jays shed all of their head feathers from the capital tract at once and were bald. But the primaries, greater primary coverts, and alula feathers were retained in the basic plumage. This molt, between early June to late September, took 140–170 days.

Definitive prebasic molt – All primaries P1–P10 were lost in sequence, beginning with the inner P1. The molting of the primaries averaged 90–120 days. The secondaries and tail molts began between the losses of P3 and P5. The 6 pairs of tail feathers started with the central pair and progressed outward to the two outer #6 feathers. [v18]. The body molt occurred over the hottest two months, July and August. Completion of the body molt took several more weeks. The timing of molting in relation to the nesting cycle varied [b29].

American Crow nestling's plumage

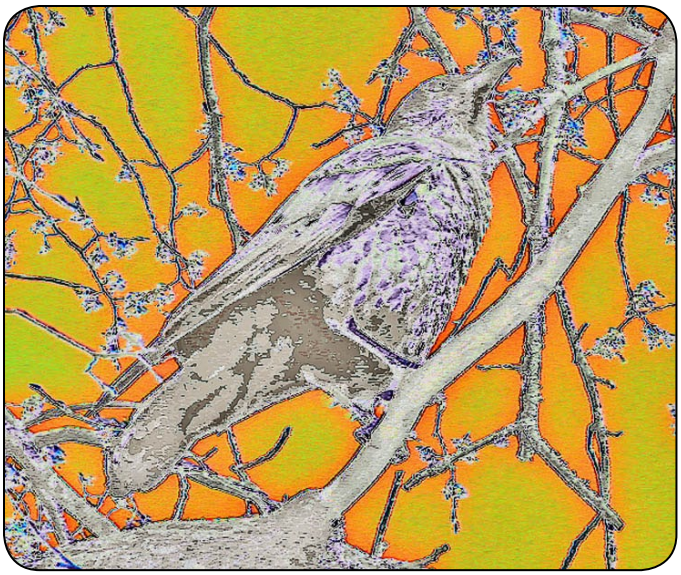
1 May to 31 May, 2000

I have arbitrarily chosen 1 May as a starting point to describe the general development of feathers

from a nestling's to an adult plumage on a typical American Crow. To make the time line easy to follow, this one crow had a hatching date of 1 May and a nestling period of 31 days (all of May). It fledged on 1 June 2000.

A newly hatched nestling on 1 May 2000 has 6 tracts of light gray, downy feathers covering only a few areas of its pink-skinned, mostly naked body. The natal down has little variation among nestling crows.

The 6 tracts of downy feathers are replaced (molted) as grayish vaned feathers began to grow. This **PREJUVENILE** molt, or **FIRST PREBASIC** molt, involves the acquisition of a juvenile plumage (or first basic plumage) by the nestling crow before it fledged on 1 June 2000. Naked parts of the skin turn from pink to a darkish gray during the first week in the nest. Soon the covering of



feathers allows the nestling to regulate and maintain its body temperature.

During the 31 days of a nestling's growth, its primary flight feathers emerge from their sheaths on days 13 or 14 [20b]. From days 24–30 the primaries were 7.5–10 cm long. Primaries of a Northwestern Crow reached the ill-defined brush stage when the nestling had completed 42% of its time in the nest, and were at 13% of the length of primaries of a newly fledged crow [v13]. The belly area of a nestling is the last to be covered with dull, dark grayish feathers. Some crow watchers have written about a slight glossy violet sheen on some nestling's feathers, while others have not. My pictures of Tarsus reveal a bluish / purplish sheen on some secondary wing feathers. Juveniles, with their matt, dark gray and flimsy contour feathers (**Juvenile Plumage**) can be separated from autumnal yearlings and adults based on the bluish sheen on darker feathers of the two latter age groups.

Juvenile plumage

1 June to 31 December, 2000

On 1 June 2000, the nestling fledged (left the nest tree). The fledgling period lasts a week or two. The feathers acquired as a nestling continue to grow as does the fledgling. Within 2 weeks the fledgling will alight and take off from the ground, and is then known as a juvenile crow. Now in its **FIRST** summer it learns to feed itself, and starts a partial molt, its **SECOND** molt, that lasts into its first autumn in 2000.

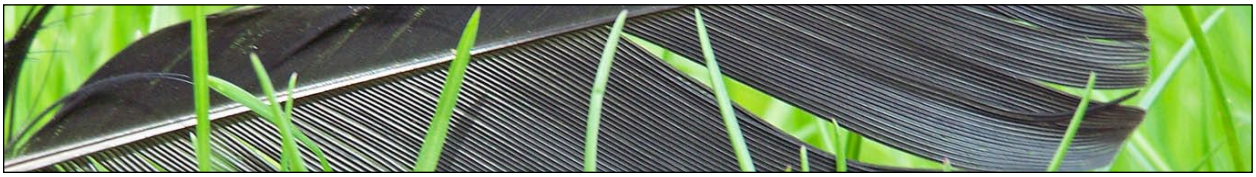
A partial molt has been described as a preformative molt. It starts in the first summer and provides stronger feathers to help insulate and protect the young crow during its first winter. The new body feathers are more compact and closer together [47h].

Retained juvenile wing coverts and flight feathers are worn, and have a brownish cast, or subdued color through early 2001. For the **first prebasic molt**, 24% of 34 crows molted 0–3 greater coverts. Their tertials, secondaries and rectrices (tail feathers) were not shed. The crow exhibits a molt limit as a juvenile in its first summer [10p].

Actual duration of the molt in the American Crow is unknown. For the Rook (a European corvid found from Ireland east to Japan), Witherby noted it in July and August. The Rook's feathers retained over the first winter (2000–'01) –

(1) main wing feathers (remiges)
(2) alula
(3) primary coverts
(4) most of the greater coverts (the 2 innermost are molted)
(5) tail feathers (rectrices)

For the Rook over the summer, "the molt commences on the back and flanks, and the whole



body and wing coverts are soon involved, the head being the last to molt" 17w.

Once the American Crow's partial **molt** was completed in the autumn of 2000, the young juvenile had acquired its plumage for the first winter of 2000 and first half of the year 2001, at which time it is known as a yearling, or sub-adult. By the crow's calendar, it will not be a full 12 months old until 1 May 2001, a year from its hatching date.

Yearling plumage

1 January to 31 December, 2001
The juvenile plumage is completely replaced during the preyearling molt into the plumage of a yearling crow (AHY – After Hatch Year) in the summer / fall of 2001. For the first 5–6 months of 2001, the yearling retains the dull juvenile plumage. This **THIRD** molt over its **SECOND** summer into the autumn of 2001 generally lasts from May to the end of September. All of the feathers are replaced by the early winter. Before they are molted, the worn brownish juvenile primary wing and tail feath-

AMERICAN CROW In August, as the feathers continue to molt, some crows begin to resemble Leonard Baskin's, The Crow (1958), ink on paper

AMERICAN CROW A breeding bird in mid-April displays its bluish-black, sexy plumage as it gathers shelled peanuts to store (cache) on its territory in Winnipeg **Manitoba**

ers are about a year old and were formed during the **FIRST** molt when the crow was a nestling in May 2000. The tips of the tail feathers are quite abraded, and some probably have fault bars. The yearling now molts its primaries, secondaries and rectrices for the first time since it left its nest. The body and head feathers are also replaced, for the second time, in 2001. This produces an adult looking plumage by the early winter of 2001. However, this crow did not breed in 2001.

For a crow 16–18 months of age, now in its breeding plumage, the feathers have a glossy bluish to violet sheen on the upper (dorsal) side. This is the plumage of the crow's 2nd winter 2001–'02, and breeding plumage in the spring of 2002. This crow might acquire a territory and mate in early 2002, its first nesting season.

Yearlings in **Illinois** molted their original juvenile secondaries and tail feathers in May. This was before adult crows began their molting about June [20b]. It was estimated this molt was finished sometime in September [10p]. Feathers on the upper back (mantle) and scapulars of the American Crow are scale-like in appearance because the distal 1–2 mm of barbs of the feathers do not interlock [j38].

Adult plumage

1 January to 31 December, 2002

The yearling plumage, acquired in the summer of 2001, resembles the adult plumage by the early winter of 2001–'02. This crow then begins its first complete molt as an adult in the summer of 2002. By our calendar, the crow is referred to as an adult on 1 January 2002. By the crow's calendar, it won't be an adult (2 years old) until 1 May 2002, 24 months after it hatched.

American Crow preening its chest feathers

After 2002, the crow molts into its adult breeding plumage each summer for the remainder

Large crow feathers are starting to be shed and found from early June through mid-September. Crows retain their powers of flight throughout the molting process

of its life. This **definitive plumage** is "a plumage whose aspect does not change with time." A crow displays a similar looking plumage, whether it is 4 or 8 years old. The adult plumage, obtained by a complete molt, is the one we typically use to describe the look of a crow 47h. It is the plumage painted by artists, except perhaps Baskin.

Since there is no breeding and nonbreeding alternate plumage for crows there is no **Prealternate Molt**, which is "the molt by which an alternate plumage is attained" 47h. Female crows do not have a separate (cryptic) plumage to hid them while they are incubating. The plumages of the sexes look alike to us (but not to them) all the time.

Observations on molting and color

Feathers

Entering July in **Winnipeg**, the body molt of juvenile crows was not noticeably underway. The eye retains a little blue. Their high pitched caws, skinny appearance, and skittishness to unexpected movement, even from a nearby mallard, helps to identify them in the field. It seems to me the roughness obtained from molting body feathers was visible mainly in August and early September; especially at the sides and back of the neck. A few crows overhead in mid-September still had gaps due to their dropped secondary wing feathers. K Lorenz "I have repeatedly observed the first adult molt or the correlated appearance of sexual maturity results in an improvement in the general health of weakly Corvids" l72.

As I walked about **Winnipeg** in early June, I began to find large primary and tail feathers on the ground. June was the month when most young crows fledged from their nest tree. Molted feathers were sometimes found on the ground in September. In **Oklahoma** and **California**, Carolee Caffrey found primaries and secondaries on the ground starting about one month postfledging. Over the summer, all three groups of crows are molting – juveniles, yearlings and adults, but only the latter two are shedding the large wing and tail feathers, which you should be able to separate by their color and amount wear.

For the Carrion Crow, the molt in free-living birds lasted from mid-May to mid-September, a four month period, with the peak in August and September. The sequence of molting flight feathers starts with the inside primary (#1), and the

A newly fledged Common Raven in juvenile plumage shows its pink mouth when begging to be fed. Its parent with a black mouth is on the right. The open mouth of the fledgling, its flapping wings, and begging calls indicate its hunger. Six young left the nest on the Court House ledge in early May in **Winnipeg**, a month before most crows fledge

adjacent secondary (#1), and the middle of the 12 tail feathers. For the Carrion Crow, there are 10 primary flight feathers, 6 secondary and 5 tertiary feathers s53. Large wing and tail feathers are pulled free during the daily preening sessions. The resulting gaps from one or two missing wing feathers in overhead flying crows are most obvious in June–July.

At Cape May **New Jersey**, wing molts of American Crows were usually finished by mid-August, and that of Fish Crows lasted into September and October 47h. For the 10 primary feathers, P7 was the longest, and P10 the shortest. As well, P5 was obviously longer than P9 b15.

Primaries of Rooks in the same position on each wing were molted at the same time and new feathers started growing before the next outer primary was shed. By mid-June, half the primaries had molted and all of the greater wing coverts dropped at once. Other groups of feathers followed. The primaries took about 4 months to complete their molt. Secondary wing feathers also molted from the first to the tenth with the sequence involving a skip – the 7th was molted before the 6th feather. New feathers were dark and carried a purplish-green sheen 17m.

Eyes, bill, and feet

In addition to feather color and wear as indicators of age, the blue-gray iris of the juvenile's eye is distinctive at close range. This color is short-lived; within a few months the iris acquires the dark brown hue characteristic of an adult's eye. Below the eye is a pinkish-orange bare streak at the base of the two bills (mandibles). The commisure, where the malar and lores feather patches meet, is indicated by its bright color and bareness. About 4 weeks after fledging it appears whitish before it darkens. The feet of the juvenile American Crow are distinctive in some ways for the first few months. There is a clear horn color on the claw's undersurface e35 and I have found the toe pads softer to touch and a lighter gray to brown than those of the darker worn pads of an adult.

Mouth color and ageing

Mouth color appearance is variable in the three ages classes of crows y10 –

(1) Hatch-year (HY) juvenile crows have a bright pink palate right after fledging, which will develop some dark mottling and blackness near the bills' tips by their first winter (**photo page 163**)
(2) Subadult crows (after hatch year AHY) or yearlings, have a palate with a variable mixture of pink and black spotting
(3) Adult crows display a black palate and shiny bluish-black scapulars and wing coverts

At feeding time the pink inside a juvenile's open mouth is obvious at a distance. The acquisition of black pigment from the tip of the bill to the back of the throat may be a rather long process, still begging for completion as a yearling molts into adult plumage g34. When a yearling is nearby and facing you as it calls, some pink may

be seen. In the yearling's first early winter (by the crow's calendar), a small amount of pink would be one way to separate a yearling, non-breeding crow from an adult breeder since the two age classes now have a similar plumage.

The changes in mouth color of 17 captive Common Ravens in an outdoor aviary were followed. These birds gave results that were very different from those color stages used to age American Crows. Newly fledged ravens all had a pink inner mouth which was readily visible when the young begged for food. It was presumed an all-black mouth of an adult raven slowly developed through a mottled (pink and black) state as the bird aged. However, four highly dominant juvenile individuals developed an all black mouth (like an adults more than 3 years of age) by 8 months (the start of their AHY) after fledging. At 18 months post fledging, five other ravens remained unpaired and subordinate and still had a pink mouth. Two ravens at 22 months post fledging were still unpaired and pink-mouthed and would have been classified as less than one year of age. It appears mouth color was linked to dominance (status) and may serve as a sexual signal. Unfortunately, the mouth color was not related to the sex of any of the ravens, which may also be linked in the color transition from pink to black [h57]. I am not aware of any similar study with a small captive flock of American Crows that would help define the usefulness of palate color for ageing. At this stage in our knowledge, ageing crows by mouth color is probably not very reliable until proven otherwise. However, there is a possibility the ravens developed a black mouth color more quickly because they were captives. To verify this, marked wild ravens will have to be captured, and recaptured a few times to look for the timing and amount of color changes in their mouths.

Ageing crows from their mouth color takes practice. Estimating the ratio of pink to black in a crow's mouth can lead to inconsistencies at first. In **Nova Scotia,** crows from a large roosting flock were captured, aged and banded. Upon recapture, agreement in ageing the birds with the first capture was 95 and 98% within the same year. Between seasons, the ageing of recaptured crows produced an accuracy of only 68–77% over two years. The problem, as always, was in separating yearlings and adults. The ageing accuracy was 100% when the overwintering crows were in only two categories – juveniles and older birds [25m].

Bursa of Fabricius

The bursa is an epithelial and lymphoid organ that is found only in birds. It is necessary for B-cell development, which is part of the specific immune system. It is present in the cloaca of birds and is named after Hieronymus Fabricius who first described it in 1621 (wiki).

Juvenile Clark's Nutcrackers in the summer had a bursa of Fabricius weighing 300 milligrams (mg), which decreased in weight by October of the bird's first year. By the next spring (April) the nutcracker's bursa usually weighed less than 50 mg or was absent [18m].

Two age classes

Working with only two age classes, the how, where and when crows were collected influenced the distribution of age in the sample. From wintering flocks in **Nova Scotia**, American Crows were live-trapped and shot. Trapping gave a ratio of juveniles 65%, and older birds 35% (yearlings and adults). Shot crows yielded a ratio of juveniles 51% and older birds 49%. The shooting sample appeared to be more accurate. When trapping birds, juvenile crows were less wary and more likely to enter a baited trap before the adults, which overestimated the percentage of juveniles in the roosting population. Overall, it was suggested the roosting ratio was close to juvenile 60% and older birds 40% [25m] . From crows shot at five roosts in **Illinois**, juveniles ranged from 29–47% of the population [20b].

At the Essex County winter roost in

southwestern **Ontario**, 4,400 crows were shot over wintery fields away from the large roost when they came to carrion, decoys and calls. What level of bias was introduced by these methods is unknown, but overall averages for two winters came to juveniles 55% and older crows 45% c41. If accurate, these figures represent a healthy reproductive rate for the American Crow in Ontario. It would be interesting to repeat the experiment to determine if West Nile virus has changed the ratio of the age groups.

When I visited the roost of crows in Chatham **Ontario** in mid-December 2011, the 10 dead crows (some dead for over a week) checked on two mornings, after the birds had left for the day, were juveniles. It would be a worthwhile project to visit accessible roosts of about 20,000 or more crows in various locations in North American on a daily / weekly basis. A report on the sex and age of dead crows would be worth having to establish the rate of dying, and perhaps reasons among the age classes over the winter.

Sexing crows

Unlike the pintail, feather color does not indicate the sex of the American Crow. Crow banders mark the sex of the crow **'U'** for **U**nknown on the form. With a dead crow, an incision is necessary to locate the girl or boy organs. In the field, relative size differences and behavioral traits are often signs of a crow's sex. Genetically, the sex of birds is determined by the Z and W sex chromosomes, rather than by the X and Y chromosomes present in mammals. Male birds have two Z chromosomes (ZZ), and female birds are heterogametic with a W chromosome and a Z chromosome (ZW)" h22. To accurately determine the sex of living marked crows, field researchers remove a tiny volume of blood from a wing's brachial vein for analysis.

Weight

From **Nova Scotia**, the weights of American Crows indicated the male, with an average weight of 598 grams, was about 9% heavier than the average weight of a female at 545 grams 25m. These crows, in the Annapolis Valley of Nova Scotia, I should add, are by far the heaviest birds recorded for the species. From there, the crows to the south and west generally weigh less.

In **Nova Scotia** the male juveniles exhibited a 32% weight variation and older birds a 56% variation. Females juveniles had only a 12% weight variation and older birds 15%. Females may be smaller to compensate for weight gain when eggs are forming, yet still remain efficient in the air during the early part of the breeding season 25m. For roosting crows in **Ohio**, there was a 210 gram range for male crows (all ages) and a 194 g range for all females h92.

The male Fish Crow in **Florida** outweighed the female by 10% b56. The 10% weight difference between the sexes is not always apparent to a human observer in the field, especially when a bird is alone or in a large flock. When a mated pair on their territory are studied long enough and at close range, there is a good possibility they can be sexed at least some of the time when beside each other.

194. American Crow, Dead © by Alison Kent, with permission

WEIGHT – averages and ranges of American Crows compiled from 7 states and two eastern provinces. **454 grams = one pound**

■ **GEORGIA** j38 1941
Spring and summer, all ages, shot

A day in the life of a crow includes perching. This one sat for 3 minutes on an overhead wire while making the rounds on its urban territory

AF 397 (359–444) grams (n 37)
AM 447 (396–513) grams (n 33)
JF 387 (324–438) grams (n 17)
JM 421 (368–466) grams (n 20)

■ **ILLINOIS** 20b 1941
Winter roosts, all ages, dynamite
AF 474 grams (n 245); AM 538 grams (n 248)
JF 459 grams (n 203); JM 511 grams (n 160)
Overall averages, all ages **F 468** grams;
M 530 grams (n 856)
Mid-May, shot
BF 458 grams; BM 533 grams (total n 32)
JF 437 grams; JM 498 grams (total n 69)

■ **LOUISIANA** l32 1950
Seasonal, shot
F 431 (400–490) grams (n 13) autumn
M 458 (411–489) grams (n 15) autumn
F 472 (385–552) grams (n 16) winter
M 503 (453–562) grams (n 14) winter
F 440 (371–497) grams (n 32) spring
M 463 (419–506) grams (n 42) spring

■ **OHIO** h92 1935
February roost, all ages, shot
F 491 (416–610) grams (n 45)
M 541 (436–637) grams (n 30)

■ **OKLAHOMA** i10 1939
December roost, all ages, dynamite
F 421 grams (n 474); M 476 grams (n 526)
Overall average 451 grams (n 1,000)

■ **OKLAHOMA** a11 1944
February roost, all ages, (total n 310)
F 446 grams; M 502 grams *Cb brachyrhy.*
F 427 grams; M 473 grams *Cb hesperis*

■ **WISCONSIN** s45 1938
March roost, all ages, dynamite
F 496 (402–588) grams (n 44)
M 487 (330–576) grams (n 45)
Adults 492 (419–567) grams (n 23)
Juveniles 498 (335–588) grams (n 54)

■ **NEWFOUNDLAND** a46 1974
Winter, a few in summer, shot
AF 516 (460–613) grams (n 19)
AM 534 (327–621) grams (n 37)
Juveniles 522 (438–665) grams (n 40)

■ **NOVA SCOTIA** 25m 1983
Winter roost, all ages, shot
F 545 (354–695) grams (n 107)
M 598 (366–746) grams (n 97)
JF 529 (366–665) grams (n 50)
JM 594 (366–746) grams (n 61)
Overall average, all ages, both sexes 570 grams (n 315)

(n 203) is the number of crows sampled
AF Adult Female; AM Adult Male
JF Juvenile Female; JM Juvenile Male
BF Breeding Female; BM Breeding Male

Using our 12 month calendar, if any crows were collected after 31 December, by our unnatural avian ageing system, there would be no juveniles in the population, only yearlings and adults.

A small sample of 15 American Crows was obtained in late spring and summer in **Georgia**, and 28 Northwestern Crows from **Washington** j37.

Georgia – AMERICAN CROWS

One first-year female

body weight 414 grams
heart weight 3.06 grams
heart weight / body weight: 414 / 306 = 1.35

6 adult females

average body weight 403 (373–444) grams
average heart weights 3.3 (2.9–3.8) grams
heart wt / body wt 1.2 (1.1–1.3)

8 adult males

average body weight 448 (415–509) grams
average heart weight 3.7 (2.8–4.4) grams
heart wt / body wt 1.2 (1.1–1.5)

Washington – NORTHWESTERN CROWS

One first-year female

body weight 349 grams
heart weight 3.04 grams
heart weight / body weight: 349 / 304 = 1.15

8 adult females

average body weight 368 (315–421) grams
average heart weight 3.5 (3.0–3.9) grams
heart wt / body wt 1.1 (0.9–1.2)

19 adult males

average body weight 415 (389–486) grams
average heart weight 3.7 (3.0–5.1) grams
heart wt / body wt 1.1 (0.8–1.3)

Measurements

Circling the sexual differences, numerous measurements have been made to find clues that would permit crow watchers to easily sex a crow in the hand without taking a sample of blood. So far, no completely accurate system has evolved. There is too much overlap in the measurements. Let me briefly review what has been tried.

Nova Scotia

Eight measurements were made of wintering crows. In groups they were –

(1) total length and weight
(2) wing and tail length
(3) tarsus length
(4) two bill lengths and bill depth

Juveniles were significantly smaller than older birds in five of the eight measurements. As well, in both age classes, males were significantly larger than females in all eight measurements [25m]. These conclusions do not alter those reached earlier by Johnston in 1961 [j38]. In **Nova Scotia**, males (juveniles and older crows) were 5% and 6% larger than females in the same age class. These small percentages produced a sexual identification accuracy of 80% for the juveniles and 91% for older birds. Of the eight measurements, the bill size revealed the highest degree of sexual difference. Even so the differences were slight. The average total bill length and depth for adult females was 4.9 and 1.7 cm compared to 5.3 and 1.8 cm for adult males [25m]. Measurements among other corvids, including skeletal data, have not obtained a consistent 100% accuracy to determine the sex.

Due to the impact of West Nile fever on populations of American Crows, there was an increased emphasis to determine the sex and age of crows in the field [y10]. The problem was compounded by size differences of crows in different regions of North America. Discriminate function analysis arrived at a statistical separation in the genders of the three age groups –

(1) hatch-year, or juvenile (HY)
(2) subadult, or yearling (AHY)
(3) adult crows (Ad)

Illinois

In Champaign County in 2001–2002, dead crows and trapped birds were sampled. A small number of live crows were radio-tagged. Seven measurements were made–

(1) Unflattened wing chord from the blunt end of the wrist bone to the distal tip of the longest primary
(2) Tail length from the point of insertion of the rachis of a middle tail feather to the distal tip of the feather
(3) Tarsal length on the right leg from the joint

between the tibiotarsus and the tarsometatarsus to the distal edge of the most distal [undivided] scale covering the base of the forward-pointing toes
(4) Bill length from the start of feathering of the exposed culmen at its base [a somewhat variable starting point] to the distal tip of the bill
(5) Bill depth at the anterior (distal) point of the nostrils
(6) Bill width across the bill above the rear (proximal) point of the nostrils
(7) Head-to-bill length from the occipital ridge at the back of the skull to the tip of the bill.

Heavily worn or growing feathers were not measured.

The six average measurements below for American Crows are copied from y10. Using age-specific statistical analysis, there was almost a complete success for sexing crows of different age classes – HY 100%; Sub-Adult (100%); and Adult 89%.

(1) FEMALE HATCH YEAR (n 112)
Wing chord 29 cm
Tail length 16.7 cm
Tarsus length 5.6 cm
Head-bill length 8.6 cm
Bill length 4.5 cm
Weight 409 grams

(1a) MALE HATCH YEAR (n 24)
Wing chord 29.8 cm
Tail length 17 cm
Tarsus length 5.8 cm
Head-bill length 9.1 cm
Bill length 4.9 cm
Weight 455 grams

(2) FEMALE SUBADULT (yearling) (n 12)
Wing chord 28.7 cm
Tail length 16.6 cm
Tarsus length 5.5 cm
Head-bill length 8.7 cm
Bill length 4.7 cm
Weight 429 grams

(2a) MALE SUBADULT (yearling) (n 14)
Wing chord 30.6 cm
Tail length 17.6 cm
Tarsus length 5.8 cm
Head-bill length 9.1 cm
Bill length 4.9 cm
Weight 491 grams

(3) FEMALE ADULT (Ad) (n 14)
Wing chord 30.7 cm
Tail length 17.6 cm
Tarsus length 5.7 cm
Head-bill length 8.9 cm
Bill length 4.9 cm
Weight 438 grams

(3a) MALE ADULT (Ad) (n 5)
Wing chord 31.5 cm
Tail length 17.8 cm
Tarsus length 5.9 cm
Head-bill length 9.4 cm
Bill length 5 cm
Weight 505 grams

The sizes of bill depth and width were also given, but I chose not to list them above. The average lengths of tarsi ranged from 5.5 cm (F Sub-A) to 5.9 cm (M Ad). This was the only measurement

which was as big in (HY) juveniles as in adult crows.

Georgia and **South Carolina**

From the southern parts of Georgia and South Carolina, 576 birds of 97 species were shot and weighted in the summer (1947–'56) after nesting was over. A small sample of American Crows provided these average figures –

Female HY or AHY 395 grams (n 3) July
Female Adult 395 grams (n 8) June
Male Adult 460 grams (n 6) July [n34]

Saskatchewan

Around Saskatoon, from late April to early July of 1985–1989, crows were shot on breeding territories and at a summer roost. Once the measurements were taken, the crows were dissected and sexed. Over all ages, males were larger than females, especially as adults. Using wing, tarsus and head-bill measurements for adults, a discriminant function analysis classified 92% of crows correctly for sex. Additional measurements did not help to correctly sex four males that slipped through the initial statistical filter. Only males were occasionally wrongly identified as females. If a researcher was pressed for time, 87% of adult crows (n 104) were sexed by wing chord length alone. Adult males (86%) had a wing length greater than 31.1 cm and 88% of adult females had wing lengths less than 30.8 cm. Yearlings exhibited a wide overlap in sizes, and four measurements provided only an 80% sex-classification success. Yearling females had a longer bill than adults. Some measurements were difficult to take, ie. toe length and bill width, so they were discarded. Feather wear was minimal and did not affect the results [c73].

Geographical size variations revealed regional differences. It is unlikely one system of measurements can be used for the entire North American crow population. Next is a comparison of the sex-related sizes of two age classes of American Crows in the same 1980s study [c73].

Sample sizes ranged from 12–56 crows –

Yearling Crows	Female	Male
Wing Chord Length	29.5 cm	30.5 cm
Tail Length	16.6 cm	17.1 cm
Tarsus Length	5.7 cm	5.9 cm
Bill Length	3.2 cm	3.4 cm
Bill Depth	1.6 cm	1.6 cm
Head–Bill Length	8.7 cm	9.1 cm

Adult Crows	Female	Male
Wing Chord Length	30.1 cm	32 cm
Tail Length	17.1 cm	18.1 cm
Tarsus Length	5.6 cm	5.9 cm
Bill Length	3.1 cm	3.4 cm
Bill Depth	1.6 cm	1.7 cm
Head–Bill Length	8.6 cm	9.1 cm

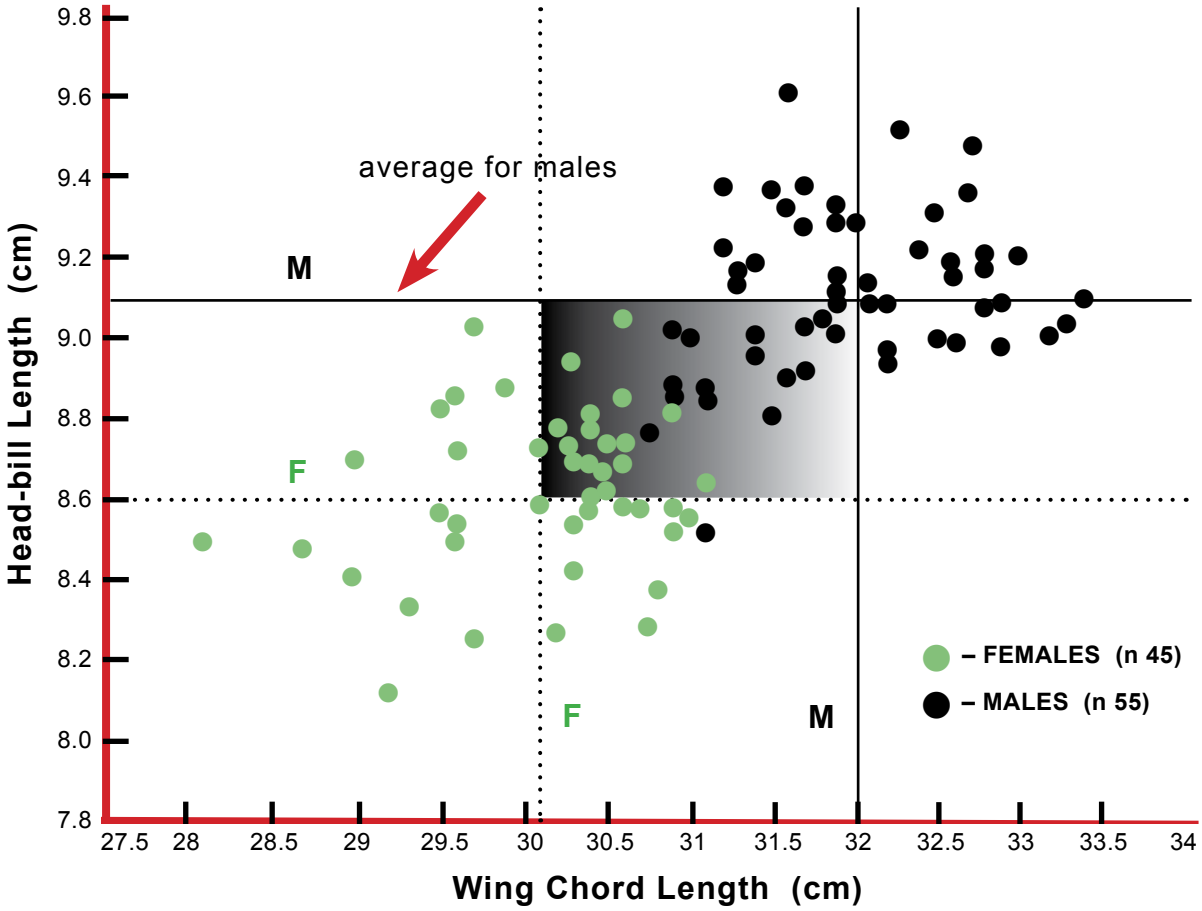
Kentucky

There are always exceptions. In central Kentucky at Lexington, a male crow was shot on 10 September 1947. If sexed correctly, it was one of the smallest with a wing chord length of 26.8 cm [16m].

An edgy lookout

Quebec

In southern Quebec, 138 American Crows were submitted by the public in response to a call for WNV carcasses. Mean weight was lower for carcasses that tested positive for WNV compared to those with a negative outcome among juveniles, yearlings and adults. But it was impossible to



199. The rectangular gray area shows the overlap for wing chord and head-bill lengths of adult American Crows in **Saskatchewan**. The smaller males **(M)** approach the larger sized females **(F)** (the 4 lines are the sexual averages) c73,

know if the weights differed before the birds died. After 8 external measurements were taken, and with all age groups combined, only 64% of the males were correctly sexed based on wing chord length, head-to-bill lengths, and weight. And only 80% of females were correctly sexed based on the same 3 measurements. Age of a crow was the best variable to include when prediction of its sex was necessary l78.

Common Ravens in Wyoming

Ravens, another corvid with similar looking sexes, were measured to find a sexual difference. Ravens were captured in Jackson Hole, Wyoming, from one of the most concentrated populations in North America. Most of the 270 ravens were caught in the fall / winter. From this sample, 56% were female and 44% male based on analysis of DNA from blood. Using two measurements – footpad length and body weight, together and separately in analysis, the footpad length alone was the most accurate. Its length correctly identified 85% of males and 91% of females. Since males have bigger feet than females, a male raven's footpad averaged 9% longer than the female's. When they used 2 discriminate functions (weight and footpad length) in conjunction, they correctly sexed 91% of the males and 97% of the females, but an unknown category (15%) was added. More ravens will have to be tested over the warm season to define the overall accuracy of these two measurements.

NOTE – in 2007, the cost of genetic determination of a bird's sex was $2.50 b73.

Juvenile American Crows begin to explore their parents' territory which includes the roofs of homes in **Winnipeg**

Sex ratio

Once the ability to age and sex a crow is realized, the setting of the sex ratio in a population is the next step. Some early research based on sex ratios obtained from small samples of roosting crows in winter, suggested males overwintered further north than females. Support for this theory came from 75 crows collected in southern **Ohio**, of which 60% were female h92. Another report of 55% in favor of males came from 348 overwintering crows in the Finger Lakes region of **New York**. But when larger samples were obtained, the sex ratio melted almost to equality e35. One thousand crows in **Oklahoma**, a southern population, produced a ratio of 53 males to 47 females i10. To the north, 4,400 roosting crows shot in southern **Ontario** gave a ratio of 52 males to 48 females over two winters c41. Both these latter reports indicate a slightly higher survival rate for male crows on the continent, assuming the hatching ratio and survival of nestlings and juveniles are sexually equal.

Diseases

THE POOR SICK CROWS

Some musty corn
That had started to rot,
Was thrown one day
On a farmer's back lot

And every crow,
Who a share did take,
Was quickly laid low
With a belly-ache.

And each called a doctor,
Who lived right near'm,
And was shot with pills
And pumped with serum

But they couldn't cope
With the strange diseases;
So they called in doctors
From over the seas.

But in spite of these men,
Who were learned and great,
The crows died off
At an awful rate.

"Bad corn has done it"
Said the medicoes,
As they pumped more serum
In the poor old crows.

Then a lay-crow said
With a touch of scorn:
"Why don't you tell the crows
Not to eat the corn?"

And the doctors all,
Who in conclave sat,
Said: "Isn't it funny
That we didn't think of that?"

– Wilson MacDonald 1930 m06

Crows die in many ways. Since many hunters and birders still believe and perpetuate the myths that crows are the enemy of farmers and songbirds, hundreds of thousands are killed for sport each year when our insensitive index finger pulls a trigger. Other crows die from diseases and injury. In December of 1901, about 1,000 crows perished. A contagious malady known as roup spread through the birds at the Canandaigua roost in Ontario County **New York** e02. They suffered from inflammation about the head and mucus dripped from their nostrils. A membrane formed over the eyes, and when only one eye was affected, it usually was the left eye. When the crows dispersed from the roost in spring, the disease ended. About 10,000 crows in one locality died from roup (ulcerative keratitis), a disease of the respiratory tract. From 1900–1915, several reports of roup came in from **Indiana, New York, Maryland** and **Virginia** k06. Crow roup is not transmitted to chickens. They have their own version of the disease. To learn how to examine a dead bird for disease, and prepare samples for laboratory analysis, read Van Riper v06.

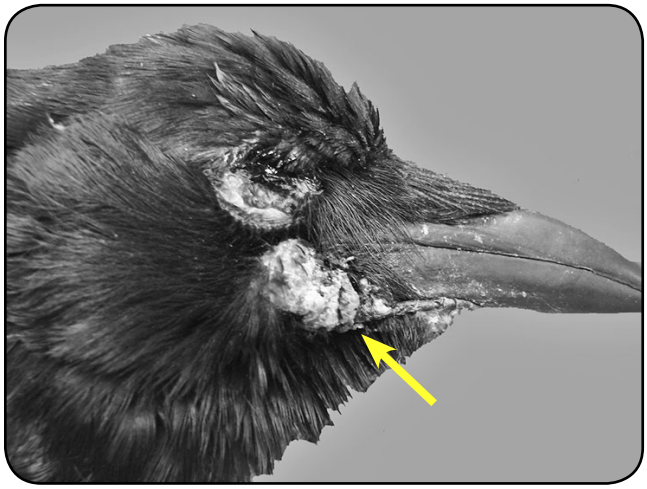
From several suburban locations on Long Island **New York**, from June 1994–June 1996, 18 juvenile American Crows showed signs of metabolic bone disease. The birds, from 5–7 weeks of age, had "either folded fractures or marked valgus of at least one proximal tibiotarsus, accompanied by paresis and inability to stand or fly." The bones were examined microscopically and showed "generalized osteodystrophia fibrosa, which occurs only in hyperparathyroidism." Nutrition seemed to be one reason, such as a vitamin D or calcium deficiency; another could have been chronic exposure to xenobiotics (synthetic chemicals) through the insects in their diet t05.

At a wintery roost in early 2000 at Poughkeepsie **New York**, crows died from West Nile fever and other causes d27. From a sample of 85 WNV-negative birds, deaths were due to –

(1) traumatic injuries 52%
(2) predation 16%
(3) avian pox 14%,
(4) pneumonia 12%
(5) poisoning 6%

From western **Ontario** in February 1928, tubercular lesions, chiefly on the liver, spleen and gizzard were identified in 6 of 40 dying crows 29m. Doctors attempted to transmit two strains of crow tuberculosis to a few other bird and mammal species, without success. Later, from 263 crows in **Ontario**, 10% had lesions cause by tuberculosis. From the 25 infected crows, lesions were identified in livers (92%), spleens (32%), lungs (8%) and other parts of the body (16%). Seven strains of tubercle bacilli were found in the lesions. *Mycobacterium avium* was thought to be the cause, even though it was modified in the crows. When this organism was inoculated into chickens, guinea pigs and rabbits, the results were erratic. The chickens gave a chronic response rather than a rapid one. In all the animals experimentally infected, the level of emaciation that developed was more than expected based on the amount of lesions found at autopsy. The crows showed little sign of emaciation, possibly because the infection was not generalized 30m.

In **Pennsylvania**, favus in a crow was a fungal infection that left the crow bald and its neck skin thick and scaly b79. In Bruce County **Ontario**, a young crow unable to fly, was caught and three days later it died on 19 July. It had nodules

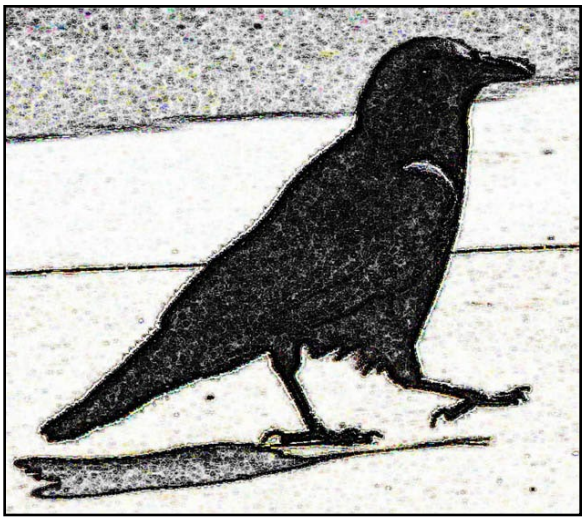


AMERICAN CROW Adjacent to the commisure of the mouth is a large proliferation mass consistent with poxvirus infection. Photograph by Andrew D Miller 21m. © SAGE, with permission

1–5 mm wide in the skin, pectoral muscles, liver, spleen, lungs and the humeroulunar (elbow) joint. The bacterium *Yersinia pseudotuberculosis* was isolated from lesions in the liver, spleen, lung and intertarsal joint h05. In June, a young crow in Saskatoon **Saskatchewan** was incapable of flight. The bird had a swollen right elbow joint. *Salmonella typhimurium* was isolated and identified in the fluid removed from the arthritic wing. In wild birds salmonella infections exist at a rate of less than 2%. Winter birds concentrating around food provided by humans appear to be the most susceptible to this infection d07.

Avian poxviruses "are large, double-stranded DNA viruses that replicate in the cytoplasm of infected cells." Over 230 species of wild and domesticated birds can be infected. The genus *Avipoxvirus* includes 10 species. It is transmissible and can cause external or internal lesions. Among 9 infected wild birds delivered to the Wildlife Center of **Virginia**, two were American Crows a03.

More deadly and rampant was the fungal disease asperigillosis. In the **Nebraska** of 1974,



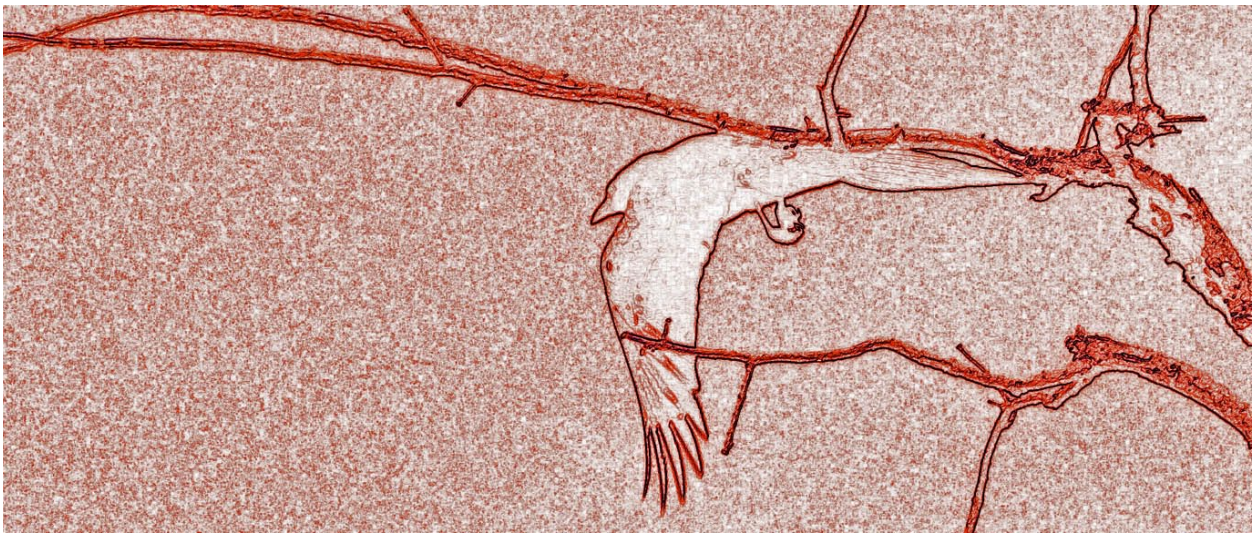
The walk of a confident, intelligent bird

migrating autumnal crows came into contact with spores and 1,500 birds died. The crows were lethargic and approachable. Captured birds died within a week. The ubiquitous nature of the spores made a pinpoint source of the epidemic impossible to define 75h. Some things in **Nebraska** did not improve over the winter. Twenty-five thousand waterfowl and about 3,000 crows died in the spring of 1975. Before dying the crows grew lethargic and had labored breathing. Chronic avian cholera from *Pasteurella multocida* killed them. A cause for the outbreak was not determined, but weather was suspected z12. Serotypes of 186 isolates of *Pasteurella multocida* were isolated from 32 species of birds. Serotype 1 was found in the above crows that died from avian cholera 79b. Lung tumors were found in 2 dead nestling and fledgling crows in Encino **California** c11.

Forty American Crows were gathered between 1 November 2006 and 1 May 2008 from the Ithaca **New York** area to determine some causes of death and prevalent diseases not related to West Nile fever in the Northeast and Midwest USA. The 40 birds had –

(1) external physical injury 15%
(2) enlarged liver and spleen 15%
(3) poxviral dermatitis (poxviruses are large complex viruses which affect skin tissue—

Tarsus, an American Crow, was found dead but not eaten on the morning of 11 June 2011. This malnourished crow lasted 10 days on the ground before she was killed. Her 3 siblings were normal and flying by mid-June. The parents, without a helper, nested successfully for several years in the same nest in the same Colorado Spruce in Winnipeg **Manitoba**



avipoxvirus) 13%
(4) pneumonia (inflammation of the lung parenchyma due to bacteria or viruses) 7%

Histologic (minute structures of tissues and organs relative to their functions) findings –

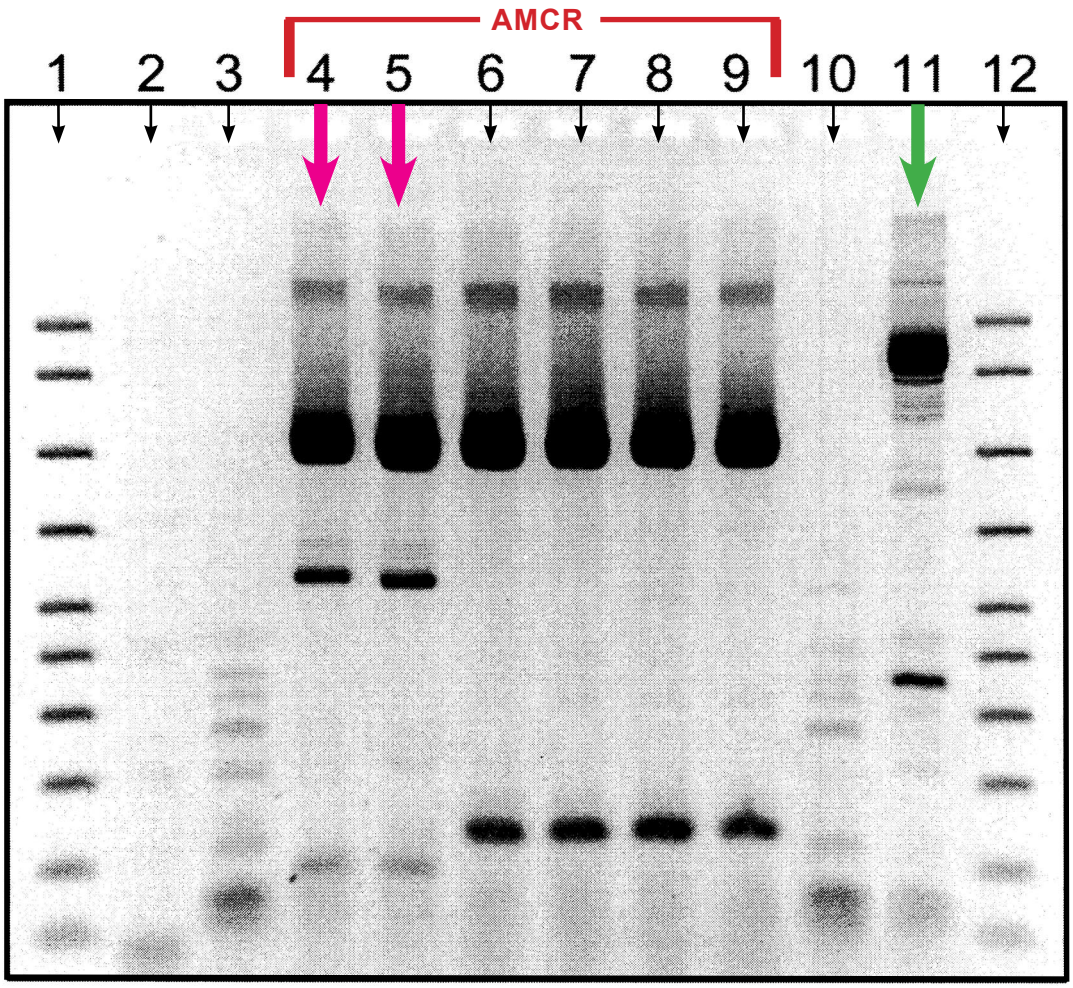
(1) endoparasitism 80%
(2) multifocal hepatic and splenic necrosis (the pathological death of one or more cells or a portion of an organ) 18%
(3) pigment accumulation in the spleen 12%
(4) disseminated bacterial infection 8%

Fungal pneumonia and poxvirus-associated lesions were the most debilitating and important diseases that would lead to death. The 6 crows with external trauma experienced – broken left femur (1 crow), multiple rib fractures (3 crows), and gunshot wounds to the thorax (2 crows) [21m].

Crows developed serum antibodies after eating rabid mouse brains and carcasses under experimental conditions. However, the crows showed no clinical signs of the disease and none of the birds died. Crows were unable to transmit the disease to mammals. It was suggested health officials use this information about crows to monitor the incidence of rabies in mammalian populations. Some 18% of 332 adult crows and 31% of 70 broods of crows contained antibodies of rabies. It appeared the best indicator of the amount of rabies in a wild mammalian population came from tests on crow nestlings right before they fledged. A problem could develop if there was an unknown virus, genetically similar to the rabies virus, capable of giving a false-positive reading. Another difficulty would be to sample the wild mammalian population to establish its incidence of rabies, and then correlate this with the rate of antibodies of rabies in nestling crows [s33].

In **Minnesota**, two nestling American Crows were examined in late 1990s. One had bilateral conjunctivitis (red eye) and severe vestibular (balance and orientation) disease. It was euthanized. The nest mate showed no clinical signs of the diseases, and was put in an avian nursery with 10 other juvenile crows. Adjacent to the crows, 6 American Robins were separated by netting. A wild Turkey was in the same flight cage as the robins, as was a European Starling. The starling died in the flight cage. All were tested for *Mycoplasma* species, even though none showed any symptoms.

From the infected crow nestling, *Mycoplasma sturni* was cultured and identified. Of the other crows in the same cage, including the nest mate of the infected crow, 8 or 73% were positive for *M sturni*. The 6 robins and one starling were positive; the wild turkey tested negative for *M sturni*. In **Figure 204** below, crow isolates in lanes 4 and 5 had the same banding pattern. Crows in lanes 6–9 had a similar pattern, but one different from



204. Random Amplified Polymorphic DNA fingerprinting. Amplified DNA was separated electrophoretically in 2% agarose gels, stained with ethidium bromide, illuminated with UV light and photographed. **Lanes 4–11** represent *Mycoplasma sturni* isolates made at the Wildlife Rehabilitation Center, St. Paul, Minnesota. Lanes I and 12 are a DNA Ladder. **Lane 2** is a negative control. **Lane 3** is the *M sturni* isolate from a Florida mockingbird. **Lanes 4** and 5 are isolates from 2 American Crow's *M sturni*; **Lanes 6–9** are from 4 different American Crow's *M. sturni*; **Lane 10** is a European Starling's *M sturni* and **Lane 11** an American Robin's *M sturni* isolate w51,

the crows in lanes 4 and 5. The starling isolate in lane 10 was different from any of the crows, but similar to the mockingbird's isolate in lane 3. The American Robin isolate in lane 11 was distinct from all the others. The crows formed two distinct groups for the isolate of *M sturni*.

This was the first report of *Mycoplasma sturni* in American Crows and American Robins. Horizontal transmission from one infected bird to the others was a possibility. But none of the birds that tested positive were tested before being admitted to the room. The origin of *M sturni* was not known. Since none of the living infected birds showed signs of illness from the bacterium, its range in the wild population was unknown as was its prevalence. The RAPD analyses showed an obvious genetic heterogeneity in the isolates w51.

Some of the causes of diseases in crows may be from inbreeding among the cooperative group. In **New York** state, blood from nestlings and tissue samples from carcasses of nestlings were gathered from 2004–'09. After genetic analysis, 299 marked nestlings were followed after fledging. By July 2008, only 100 were still alive. Appar-

Flower buds and bracts of Red-berried Elder

ently, 21 dying birds had signs of infection –

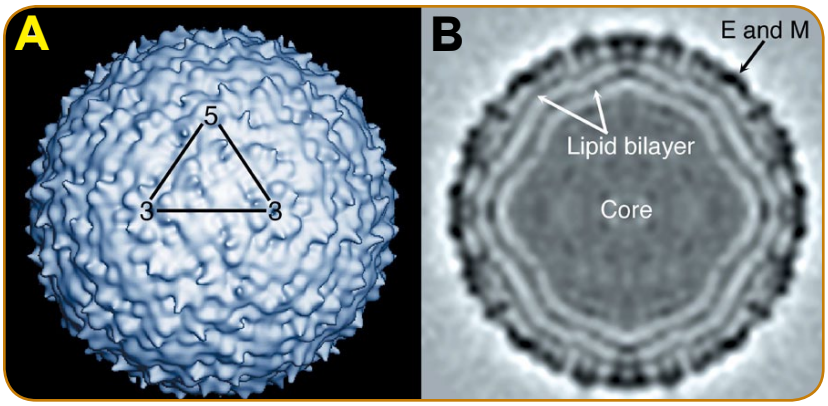
(1) 14 died from signs of infectious disease (pox viral dermatitis)
(2) 3 WN fever
(3) 2 bacterial infections
(4) 1 fungal pneumonia
(5) 1 from enteritis (inflamed intestine)

Other birds (54) died from trauma, and 124 died or disappeared from unknown causes. Although the results were preliminary, the researchers suggested, based on a bacterial killing assay and an assay for levels of immunogenicity to prevent the spread of infection, inbred nestlings were less able to ward off disease and died within their first 34 months, possibly due to poor body condition as a nestling, although this was partly supposition. Other factors such as diet may also be part of the overall picture. The mechanisms linking inbreeding to a disease are unknown t65.

In February 2003 in **Virginia,** an adult female American Crow with a poor body condition was unable to fly. On the ventral side and ahead of the cloaca (vent or asshole) was a 4 x 4 cm "multilobulated proliferated mass extending 1 cm above the skin surface." A biopsy of this mass was performed. Fungal cultures were negative. The bacterium *Staphylococcus aureus*, a common surface contaminant, was present. Adult trematodes (flukes), *Collyriclum faba*, up to 5 mm long and wide, and their eggs, 22–28 x 11–14 µm, were present. This parasite is rare in North America and may have been introduced with the House Sparrow, *Passer domesticus*. This was the first instance of a combined infection of avian pox with this trematode. An earlier record in May 1997, was of a crow hosting this trematode 978.

Who is stronger than death?
Me, evidently.
Pass, Crow.

– Ted Hughes 1971



The 17 Å structure of West Nile virus New York 99 determined by cryo-electron microscopy. **(A)** A surface shaded view of the virus with one asymmetric unit of the icosahedron shown by the triangle. The 5-fold and 3-fold icosahedral symmetry axes are labeled. **(B)** A central cross section of concentric layers of density. The outermost layer has the highest density corresponding to the E and M transmembrane proteins. The lipid bilayer is 35–40 Å thick and appears nonspherical. The core contains the genome RNA and multiple copies of the capsid protein 67m, © Science **302**: 248, 10 October 2003, with permission

WEST NILE VIRUS (WNV)

West Nile fever

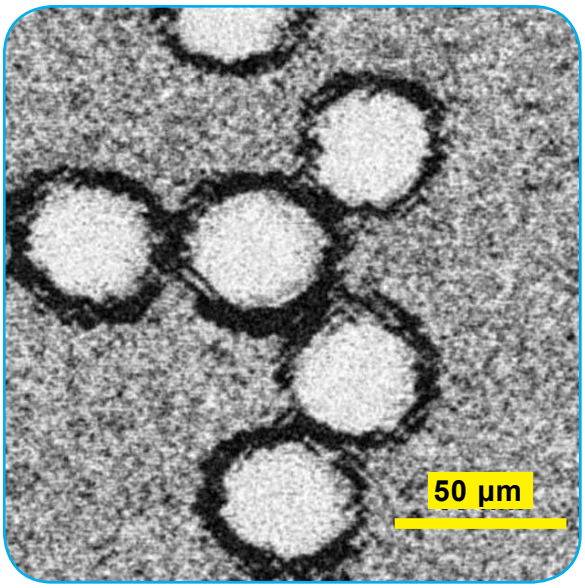
What follows is a general overview of West Nile virus, mainly in relation to the American Crow. The next 32 pages are not a thorough discussion of the virus and the infection it causes. Everything reported below is from researchers of infectious diseases, etc. Some results from earlier papers are now out-of-date, as the evolution of our understanding of the virus and its involvement with crows, mosquitoes and us changed in the first decade of the 2000s.

In the family *Flaviviridae*, West Nile virus is one of about 70 viruses that infects mainly birds. A virus is acellular, lacks independent metabolism, and is not self-replicating away from living cells. **"**West Nile virus is composed of a fairly smooth 'protein coat' or capsid that surrounds a nucleic acid core of positive-sense, single stranded RNA of about 11,000 bases (nucleotides). The nucleocapsid is contained within a spherical outer envelope about 50 nm in diameter, composed of proteins, lipids, trace metals and carbohydrates; the nucleocapsid is half that diameter**"** c65, wiki. Cryo-electron micrographs show the inner capsid is faceted. The outer envelop is round and rough.

It is known that **"**viral recombination contributes to the genetic diversity found in viruses.**"** In natural populations and in laboratory conditions, homologous recombination does happen. A data set of WNV sequences was used to look for intra-species homologous recombination but none was found. The results of a new parametric method based on the Jensen-Shannon divergence showed that WNV was not recombinant 31h.

WNV is an neuroinvasive mosquito-borne arbovirus (arthropod + virus) that causes West Nile fever in warm-blooded hosts. The infection / disease spread quickly over the United States plus southern Canada in 5 years and is now working its way into South America. In 1999 the disease arrived in North America. The first clue was a dead American Crow at the Bronx Zoo in **New York** that tested positive for WNV. In the same year 59 patients (5–95 years of age) with WNV fever were hospitalized in the New York City area during August and September n05. The disease may have arrived in 3 ways r12 –

(1) an infected human traveler was subsequently bitten by a mosquito after arriving in N. America



EM photograph of West Nile virus. Copied from wiki Sreejithk2000 Em_wnvirus_j7908i.jpg Original uploader was PhD Dre at en.wikipedia

(2) an infected mosquito that hitched a ride aboard a transcontinental flight
(3) an infected living bird brought in as a pet. An imported, infected bird **"**could pass quarantine without revealing significant clinical symptoms**"**

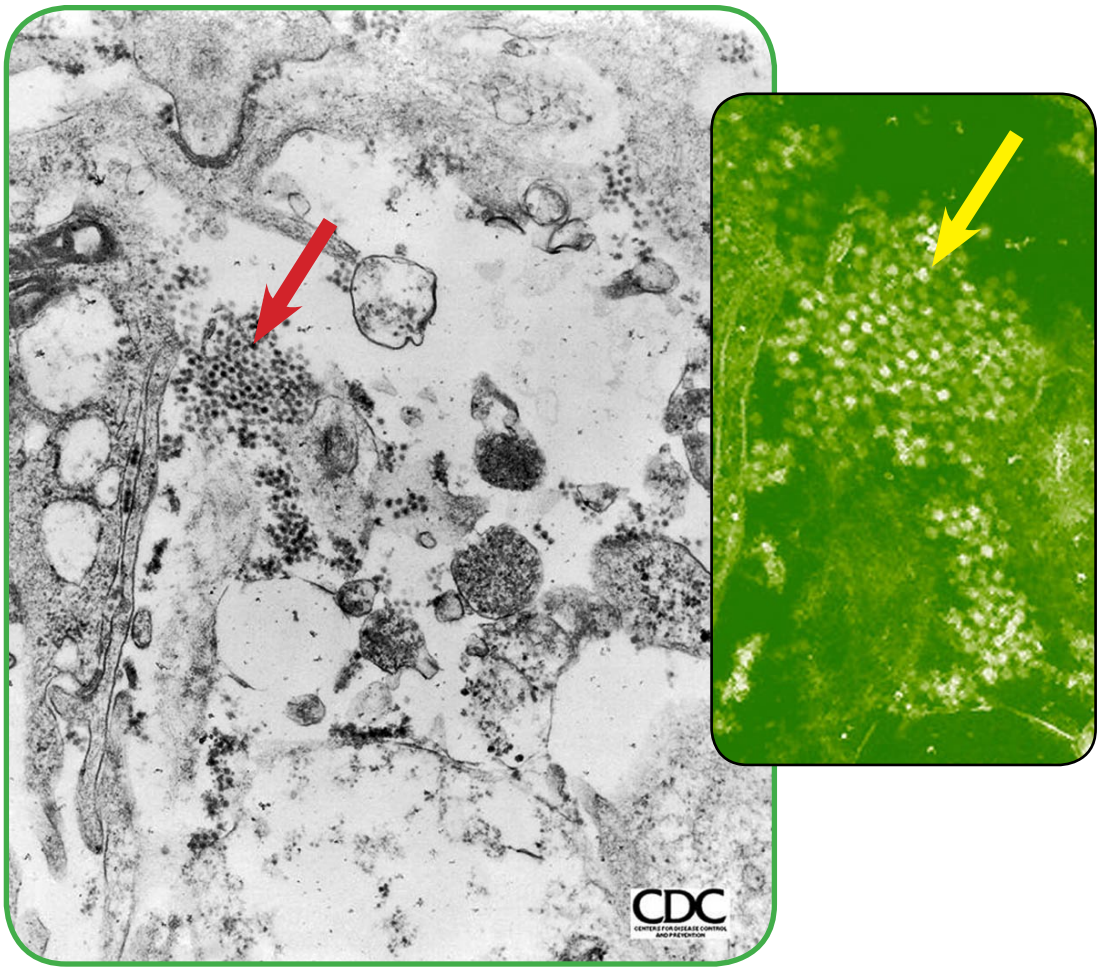
Nothing as virulent as West Nile fever had been recorded among the North American avian community. During its first pass through New York, New Jersey and Connecticut, in late 1999, 671 dead birds were tested. Confirmed cases of the fever were identified in 295 (44%) of these birds and 89% of these cases were in American Crows n05. By state, the percentages of dead birds that tested positive were –

(1) New York 39%
(2) New Jersey 37%
(3) Connecticut 77%

The spread of the disease from New York City was at a rate of 70–170 km a month, probably by birds. In the Gulf states the virus overwintered. There was no quiet period r12. In 2001 there were 48 human case of WNV encephalitis or meningitis reported in nine states from **Massachusetts** to **Florida**. The range of onset was from 13 July to 15 October and 10% or five people died. Among horses, 189 cases were reported from 15 states. A total of 4,604 American Crows and 1,497 other birds with WNV infection came in from 27 states and the **District of Columbia** c83. The spread of the virus was a steady movement outward from **New York** city with no leap-frog pattern which might be expected if migratory birds were mainly responsible for the spread of the virus. Consequently, it seemed probable the spread was due to movements of birds and mosquitoes r13, p43.

The initial cases of West Nile fever in people came in late September 1999, about two months after dead crows began to appear e18. The first case of the transmission of WNV by organ transplant was in 2002. In Toronto, **Ontario**, it was estimated solid organ transplant patients (such as myself), due to their compromised immune system, were 40 times more at risk of getting the disease than were the general public p76. In relation to people, WNV is a biocontainment level 3 agent

Homo sapiens, the great controller – at work and at play



American Crow Electron micrograph of a cluster of West Nile virus isolated from brain tissue of a crow found in New York, © the CDC http://www.columbia.edu/itc/cerc/danoff-burg/invasion_bio/inv_spp_summ/crowbrainwnvgr.jpg

l46. After contact with the virus, death follows for a few people; for many no clinical signs appear. In 1999, the genome of the virus responsible for the late summer deaths of birds and people was identified as West Nile Virus. It was closely related (99.8%) to WNV found in a dead goose in Israel in 1998 l10.

In birds not affected by WNV, their WNv-specific antibodies eliminated this virus and provided long-term protection. In other birds, especially those in the family Corvidae, some aspect of their immune system was unable to cope with the virus. **"**In addition to the spleen, 3 structures provide an environment for lymphocyte interactions, regulation, and antigen recognition.**"** f11.

(1) Peyer's patches (lymphoid aggregates in the intestinal epithelium)
(2) Cecal tonsils (lymphid aggregates near the ileocolonic junction
(3) Meckel's diverticulum (a yolk remnant of the small intestine)

American Crows

During the initial spread of the disease in 1999–2000, there developed a strong correlation in the counties of **New York** between the number of dead crows and human cases of WN fever. On Staten Island in 2000, there were 33 dead crows and 10 human case per square mile (2.6 km^2).

21 June 2009. Three large American Crow nestlings died (West Nile virus?) in seven days as the mated pair, without helpers, looked on. The arrow indicates one nestling that fell from the nest in an American Elm and got tangled in branches. Another was found dead on the street below and the third died in the nest. The following year, presumably this same unmarked pair nested 60 m away in another elm and fledged 3 young. The top crow perched on the nest is one of the breeding pair

In Upstate New York there were no human cases and less than 1 dead crow per square mile. Dead corvids, particularly American Crows, provided an early warning system for WN fever cases appearing in humans e16. Initially, analysis of the brains of dead crows revealed less than 10% had encephalitis (inflammation of the brain) but those that did "had perivascular cuffing and some death of neurons, with satellitosis and neuronophagia." However, most crows died from multisystem disorders g08.

Was there any relationship among dead crows, the testing of mosquitoes in **New York City**, and the North American wide Christmas Bird Count (CBC)? If so, the relationship was obscure. Although there were very high local declines (up to 90%) in crow abundance in Queens New York, at the continental scale the drop was not nearly as dramatic, or even detectable by such rough measurements as the CBC for North America 05h. The early figures from dead bird surveys were probably not a conclusive indicator of all impending cases of WNV in humans. Dead crows and positive pools of mosquitoes were most useful in detecting the final stage of an outbreak. The expense of sampling bird and / or mosquito populations was also a consideration.

Shortly after WNV began to spread from New York City, 10 of 14 human cases in the state of **New York** were found on Staten Island. There, more than 90% of the crows were infected, and the minimum infection rate (MIR) for the *Culex pipiens* complex was very high at 10.9. Elsewhere in the state, the lowest MIR was 0.2 in Queens. MIR is calculated as the number of WN virus-positive mosquito pools / the total number of mosquitoes tested, times 1,000. For example: 19 positive pools / 5,358 *Culex* mosquitoes tested = 0.003546 x 1,000 = a MIR of 3.5 (no units). Usually 1,000 mosquitoes constitute one pool. Also studied were the rates of infection in birds with different migratory patterns in New York state. The three groups were similar –

(1) year-round residents (n 2,924, with 38% positive for WNV)
(2) true migrants (n 51, with 43% positive)
(3) captive birds (n 25, with 40% positive) 09k

There are shortcomings in the MIR methodology –

Dead Man Called by the Bird of Paradise. Painting, © by David Scott 2011

(1) the proportion of infectious mosquitoes capable of transmitting the virus through a bite is not always the same fraction of the number of infected mosquitoes
(2) mosquito infection rates often underestimated the presence of infection in the population of mosquitoes [3b5].

Environmental factors and mosquito population data should be included in any prediction of arbovirus transmission to people. Yet, the collections of mosquitoes by county officials is not standardized as to numbers and trap locations. Furthermore, how does the use of chemical mosquito control affect the counts?

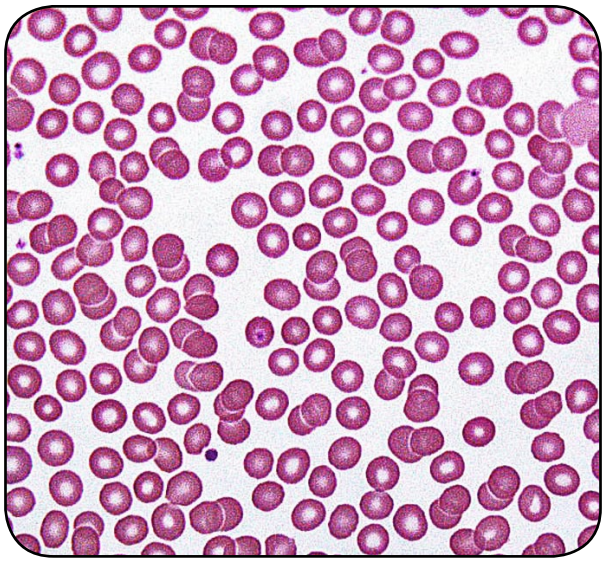
There may be early season (June–July) characteristics of crows dying from WNV that could be used to predict WNV cases in humans at the start of the spread in 2000. Using county-level mortality of crows in the northeastern states combined with multivariate analysis, it was determined that high levels of crow mortality involved –

(1) the density of dead crows per area
(2) the percentage of dead crows that tested positive for WNV times the human population was associated with reports of at least one human case of WN fever

During the initial spread of WNV, the continued surveillance of dead crows could be used to launch remedial action to minimize the disease in humans in the area where there was a large die off of crows [j60].

In 2000, over the summer, 3,403 dead birds and 9,954 pools of mosquitoes were tested for WNV in **New York** state. In the New York City epicenter, 67% of 907 crows were positive for WNV. Throughout the state 47% of 1,687 crows were positive [b96]. In **Connecticut** in September and October of 1999, WNV was isolated from brain tissue of 28 American Crows, one Cooper's Hawk, and two mosquito species – *Aedes vexans* and *Culex pipiens* [a36].

During 2000, the first full year of the disease, 10 counties in the eastern United States reported 21 human cases of WN fever. WNv-infected birds were found 44 (15–92) days prior to the first human case, and infected mosquito pools were collected 32 (4–54) days before a human case sur-



Human blood smear of normal, anucleated cells; Giemsa stain; mostly red blood cells (platelets). Each cell is 6–8 µm (microns) wide, © David G King, School of Medicine, Department of Anatomy, Southern Illinois University at Carbondale, with permission

faced. Of 7,580 crows (25% of the total reported) tested, 50% were positive for WNV [m31].

Host competence describes the degree of infectivity of an infected host. This applies to a mosquito or a bird [k67]. A competence index for 53 wild vertebrate species was calculated using an averaging system. The top 10 were –

(1) Blue Jay *Cyanocitta cristata*
(2) Western Scrub-Jay *Aphelocoma californica*
(3) **American Crow** *Corvus brachyrhynchos*
(4) Common Grackle *Quiscalus quiscula*
(5) House Finch *Carpodacus mexicanus*
(6) House Sparrow *Passer domesticus*
(7) Ring-billed Gull *Larus delawarensis*
(8) Black-billed Magpie *Pica hudsonia*
(9) American Robin *Turdus migratorius*
(10) Song Sparrow *Melospiza melodia*

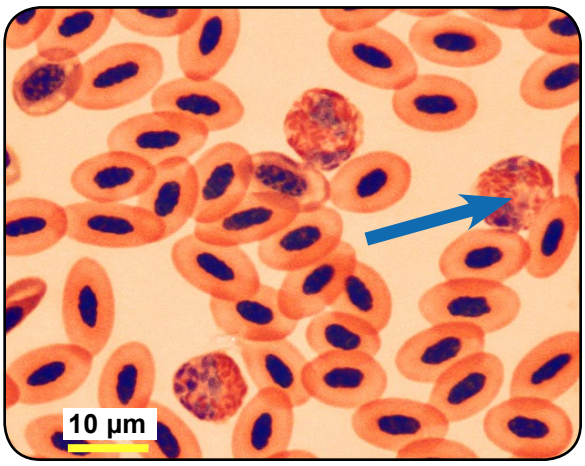
Mammals, amphibians, and reptiles often have lower viremias than birds and were fed upon less frequently by mosquitoes. Recently, the Center for Disease Control reported at least 325 bird species (exotic, captive, introduced, and native) and more than 30 mammal species (wild and domestic) have been found to be infected with WNV (wiki).

In **Connecticut**, while testing for WNV, eastern equine encephalitis virus (EEEV) was isolated from the brains of two American Crows and seven unidentified (Fish or American) Crows. The mosquito vector was *Culiseta melanura* [b72].

The advent of West Nile-fever stimulated research towards a vaccine. At the same time new strains of the virus were emerging. **"**Viral genetic diversity was greater in 2002 and 2003 at both the nucleotide and amino acid levels than in previous years due to the emergence of a new WNV genotype in 2002. The observed increase in the intensity of WNV transmission beginning in 2002 was associated with an increase in viral genetic diversity that was the result of the emergence of an additional phylogenetic clade. This genotype seems to possess an advantage over previously recognized WNV strains in mosquito transmission phenotype**"** [e07].

Genetically distinct populations of WNV were emerging as the virus expanded its range in North America. In a particular region of **Connecticut** there were nucleotide sequences from WNV cultured isolates with 30 genetic changes compared to WN-NY99. There were geographical-based clusters of mutations [a37].

With so many species of mosquitoes avail-



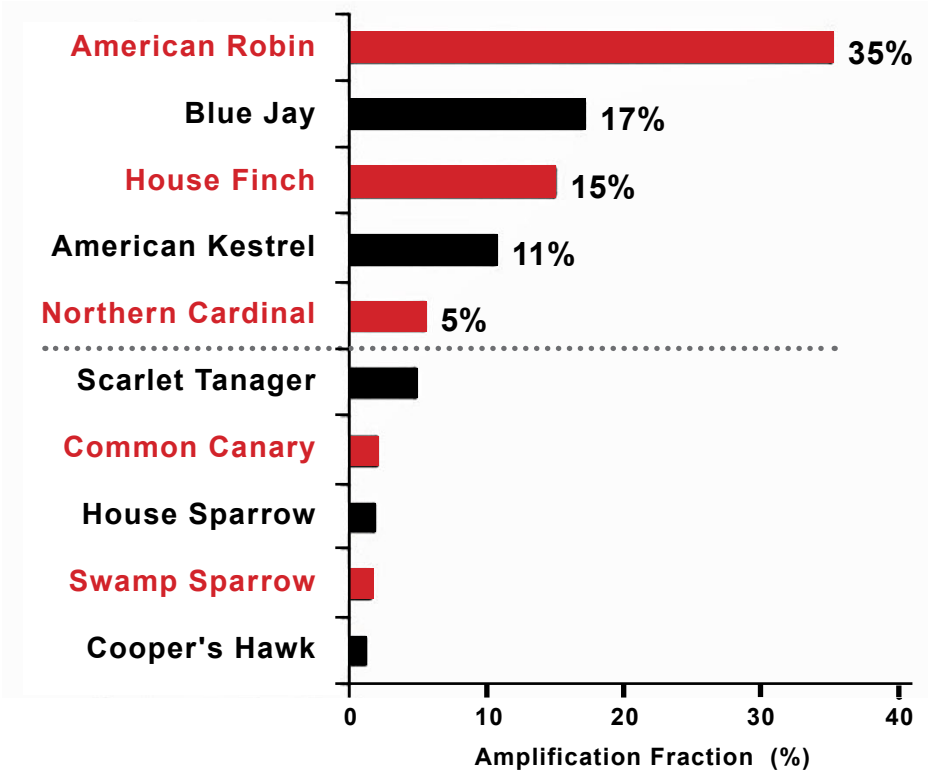
American Crow's blood with three heterophils (highly phagocytic and capable of a broad spectrum of antimicrobial activity) among the oval, nucleated red blood cells. Photomicrograph provided courtesy of Dr. T Stokol, Clinical Pathology, Cornell University, © with permission

able in any region, their abundance and feeding habits were studied. From June through October, 1999–2003 in Connecticut, 17 species of mosquitoes gave 210 isolates of WNV. Five species, *Culex pipiens, C salinarius, C restuans, Culiseta melanura* and *Aedes vexans* were thought to be responsible for most of the transmission and amplification of the disease in people, birds, horses and other mammals. In most cases there was a correlation in both space and time between the isolation of WNV from mosquitoes collected in the field and human cases. And in most years the frequency of human cases closely followed the number of viral isolations from mosquitoes in densely human populated cities, with the two peaks arriving in early September [a42].

Nucleotide variation in strains from southeast **Texas** were examined in the summer of 2002. There was a maximum of 0.35% variation from the NY382–99 strain. However, RNA viruses are "quasi-species" that have a relatively high error rate during the reproduction of their genomes. So far, there may not be strong selective pressure to ensure the emergence of dominant variants [b65].

After investigating an attenuated (less virulent) phenotype of a Mexican WNV isolate in birds "Analysis of the WNV envelope glycoprotein revealed N-linked glycosylation was not required for avian virulence or reservoir competence when examined with two important bird species, the American Crow (AMCR) and the House Sparrow (HOSP). A single amino acid residue within the helicase domain of the NS3 protein of West Nile virus (WNV), NS3-249, has been previously demonstrated to be instrumental in the viremia and mortality response in the AMCR model. Analysis of genetic substitution rates across WNV strains identified this NS3-249 residue to be under the effects of positive selection with several distinctive amino acids present at this position when comparing different WNV lineage groups" [l16].

Over the first 12 years of WNV existence



212. American Robins accounted for 35% of the WNV infections in *Culex pipiens* in suburban, southwest Chicago **Illinois** over 3 years 2005–2007. The top 5 species, including 4 songbirds but not American Crows, accounted for 82% of the WNV-infectious *Culex pipiens*. An additional 40 species had lower amplification fractions than the Cooper's Hawk [h17], © The American Society of Tropical Medicine and Hygiene

(1999–2010) in the United States, 2002 and 2003 recorded the highest number of human cases along with 284 and 264 human deaths respectively. In 2010 there were 832 cases and only 34 deaths (wiki).

The American Crow, a large common bird, is recognized by millions of people. This was fortuitous, since it was killed quickly (experimentally within 7 days) by the virus and the dead crows were readily noticed and reported by the public m99. With more precision, there were 3–5 days when crows were infectious and death occurred within 4–6 days 24w. In the wild, crows exhibited little to no seroprevalence (antibodies) w90.

Ten American Crows and 3 Blue Jays were inoculated with the NY99 strain of WNV. Both species developed clinical signs 4 days later. The inability of the birds to fly and perch may have been due to affected skeletal muscles, the central nervous system, or overall weakness due to a general infection. Several internal organs were involved in replication of the virus w48. From an infected mosquito bite, five of 9 (55%) Fish Crows that died, did so 9.6 (6–13) days post infection 01k. The antibody prevalence in American Crows was set at 5.7% (n 53), and 16.5% (n 97) for Fish Crows in the state of **Georgia** in 2004–2006. Moreover, high levels of antibodies persisted for 12 months in Fish Crows. It was easy to distinguish American from Fish Crows by using a polymerase chain reaction technique paired with restriction enzyme digestion (PCR RE) on a mitochondrial DNA fragment. This test was matched with tarsal length (except in one bird) to separate the two species w90.

A DNA vaccine was tried on Fish Crows, *Corvus ossifragus*, captured in the early 2000s in **Maryland**. Fish Crows are not as susceptible to WNV as American Crows. The Fish Crows were divided into 4 groups for administration of the vaccine, virus, and placebos. The results by group –

(1) intramuscular (**IM**) inoculation with a DNA vaccine and a viral challenge – all 10 survived **(100%)**
(2) oral vaccine and a viral challenge – 4 of 8 survived (50%)
(3) placebo inoculation and a viral challenge – 5 of 10 survived (50%)

Cottonwood

(4) room control with a placebo inoculation and placebo challenge – all 10 survived **(100%)**

The DNA vaccine was a 0.5 mg dose, IM and oral. It was administered IM at 10^5 plaque-forming units (PFU/mL) per 0.1 ml suspension. A serological (antibody) response was detected in 67% of the 9 Fish Crows that received the vaccine IM. The vaccine did not provide long-lasting protection. Oral vaccination did not produce any antibodies. A single IM dose of vaccine caused a reduced viremia (presence of virus in the blood), and held back death. One American Crow was included in groups 1 and 2 above. Both died from the viral challenge t83.

A couple of years later, a DNA vaccine surfaced that provided partial protection to American Crows from WNV 1b6. An experiment involved four vaccine formulations followed by a WNV challenge 10 weeks after the crows were vaccinated –

(1) Intramuscular (IM) DNA vaccine. Neutralizing antibodies developed in about 80% of crows, which translated into a survival rate of 44%
(2) Intramuscular (IM) DNA vaccine with an adjuvant (a substance that enhances the body's immune response to an antigen). Neutralizing antibodies developed in about 80% of crows followed by a 60% survival rate
(3) Intramuscular (IM) killed vaccine. 44%

of crows developed neutralizing antibodies and their survival rate was 11%

(4) Oral DNA vaccine. No antibodies developed and the survival rate was zero

(5) Placebo. No antibodies developed; all the American Crows died

The experiments revealed – peak viremia titers in surviving birds were much lower than titers in birds which died. The adjuvant did not greatly improve the vaccine's performance. The vaccine managed to drop the peak viremia from about 10^{10} to just over 10^{5} PFU / ml of blood. The latter level might infect about 5% of certain mosquitoes feeding on crows, thereby reducing the transmission rate. To protect valuable or endangered birds, the DNA vaccine would have to be injected into the muscle (IM) to do the most good.

The initial signs of WN fever in birds included weight loss and sleeping. Later, birds developed head tremors, central blindness, lack of awareness, weakness in legs, tilted head and catatonic states. Early on, Fort Dodge Animal Health developed a vaccine for horses known as West Nile-Innovator. It was tried on various species of birds. When American Crows were inoculated with the West Nile-Innovator vaccine, or with Japanese encephalitis vaccine, 40% survived a challenge from the WNV. All of the control crows died. Even so, getting a vaccine into wild bird populations would be very difficult and costly. However, the vaccine may be useful on captive or rare birds in zoos. Research into how the virus actually kills its victims, along with work on weather / host / mosquito relationships are needed [m40].

Crow feeding on invertebrates in a lawn

Two outside strains of WNV were tested on American Crows against the North American (NY99) strain.

(1) an Old World strain from Kenya (KEN)
(2) an Australian [Kunjin virus (KUNV)] strain

The two outside strains produced low viremias that resulted in only a few dead crows compared to all of the crows dying from the NY99 strain. More importantly, the weaker KEN and KUNV strains generated antibodies which gave 100% protection to crows against the more virulent NY99 strain in North America. An attempt is underway to find the viral genetic reasons why they are less harmful to crows [61b].

To discover why the NY99 strain of WNV was so virulent to American Crows, its growth was compared to the closely related KEN-3829 strain from Kenya that had a much lower virulence. Temperature was the key. At 44 ºC in very sick crows, replication of the NY99 strain showed only a 17-fold reduction in the RNA level. At the same temperature, the KEN-3829 strain showed a 6,500-fold reduction, which accounted for the reduced virulence of this stain to crows. NY99 continued its high level of replication as crows neared death [k71].

It was also discovered that within the WNV genotype, the NS3-249 site was key to the strength of the virulence. Natural selection for this site showed a marked increase in replication / virulence surpassing any published virulence thresholds

capable of infecting mosquitoes from crows. Sick crows lack vitality and are easily bitten by mosquitoes, which then become infected [62b].

In a 2011 article, the clinical responses in American and Fish Crows were compared. "American Crows succumbed to WNV infection subsequent to dehydration, electrolyte and pH imbalances, and delayed or depressed humoral immune responses [(HIR) is the aspect of immunity that is mediated by secreted antibodies] concurrent with marked, widespread virus replication. Viral titers were approximately 3,000 times greater in blood and 30,000 to 50,000 times greater in other tissues (eg. pancreas and small intestine) in American Crows versus Fish Crows. Both crow species had multiorgan necrosis and inflammation, although lesions were more frequent, severe, and widespread in American Crows, in which the most commonly affected tissues were small intestine, spleen, and liver. WNV-infected American Crows experience uncontrolled systemic infection leading to multiorgan failure and rapid death" [n15].

Sentinel species

American Crow or Northern Cardinal?

For many, the American Crow became the surveillance or sentinel species for West Nile fever. But challenges to the crow came from another bird. Since crows died quickly from WNV, a study of WN fever in Northern Cardinals in **Ohio** began in 2002, a year after the disease was detected in the state. Because cardinals can survive a WN infection, they were considered important in the transmission cycle. The antibody seroprevalence was 36% in females and 21% in male cardinals. Female cardinals lost antibodies to WNV after one year. Over 3 summers, 44 female cardinals fledged young from 59 nests. Thirty per cent of these females were seropositive and 68% were seronegative. One female contracted WNV in the third year. None of the nestlings from any females carried WNV IgG antibodies, and none of 23 other nestlings were positive for WNV IgM antibodies.

WN fever did not seem to influence the survival of female cardinals. However, seropositive females had half as many nestlings and fledged half as many young as seronegative females. This may be due to reduced parental care from seropositive females [m42].

In **Georgia**, it was also thought the Northern Cardinal would be a suitable sentinel species in the eastern part of the USA. From that state, 14,077 summer serum samples were collected from 83 bird species in 2000–2004, with 6.2% of the samples containing antibodies to WNV. The cardinal had one of the highest antibody prevalence rates. This, along with their extensive range and ease of capture, made them ideal for widespread serologic-based studies of WNV [g15]. Throughout **Illinois** in 2002, 1,784 birds from 81 species (wild and captive) gave serum samples against their wills. Nineteen species were positive and their overall exposure rate was 5.3%. As in Georgia, the Northern Cardinal was near the top of the list with a 12% positive reading. The American Crow showed a 3% rate of antibody prevalence [r79]. During 2001–2003, in the Atlantic and Mississippi flyways, blood samples were harvested from 13,403 migratory birds of 133 species. WNV-neutralizing antibodies were most often found in the Northern Cardinal (10%, n 762), and the Gray Catbird (3%, n 3,188). As well 19 (1%) migrant and resident birds (including one North-

A pair of fledglings 3 days after leaving their nest

ern Cardinal and 8 Gray Catbirds) in the autumn had WNV viremia (live virus). Tests results on migratory birds indicated that avian movements contributed to the spread of WNV [d78].

In **Colorado**, 1,549 dead birds from 104 species were tested – 42 species were positive. From 2002–'05, 86% of corvids, 34% of non-corvid passerines, and 37% of raptors were positive for WNV. It was suggested several more bird species in addition to the American Crow be added to the avian surveillance list. For example 45% of American Kestrels, 45% of Red-tailed Hawks and 28% of Great Horned Owls were WNV positive. Wildlife rehabilitation centers and zoos with rare birds provided the only way of knowing if this group of birds was susceptible to WNV. Rates of transmission of the virus could change greatly from year to year. In **Colorado** in 2003, 91% of crow carcasses (n 56) were positive for WNV compared to 60% (n 14) in 2005 [n12]. Some false positives ensued.

From the start, finding and reporting dead crows (an easy bird to find and identify) was a volunteer public response. In July and September 2003 in **Georgia**, researchers experimented with crow decoys and carcasses. Decoys (400 commercial ones) were placed twice and removed after 7 days. A few were moved by humans. Each decoy had reporting instructions including a phone number. Generally, twice as many decoys were detected in urban versus rural areas. The number of decoys reported in urban areas was three times the number for rural areas. Then 96 American Crow and House Sparrow carcasses were distributed twice. The remaining carcasses were removed after 6 days. At the end of day one, 48% of rural crow carcasses remained compared to 23% at the end of day 6. In urban areas, 71% of crow carcasses remained after day 1, and 29% after day 6. Camera surveillance at night showed Virginia Opossum, domestic cats and raccoons were the main scavengers on the carcasses. Ants also engaged the bodies. Of carcasses removed, opossums took 64% and raccoons 23%. Scavenger pressure was greater in rural areas. Overall 82% of crow and sparrow bodies disappeared or decayed within 6 days [w19].

In **Illinois**, radio telemetry was tried on American Crows and Northern Cardinals to study

American Robins indirectly spread WNV

their movements at roosting time in the summer. Healthy crows moved on average 1.05 km compared to 1.26 km by viremic crows. Viremic cardinals moved 55 m. It was concluded viremic crows could spread the disease over a mean area of 21 km^2 and viremic cardinals over a mean area of 0.03 km^2. With the death of so many crows, about 12% per year and up to 36% per year locally in Illinois, their drop in abundance since 2001 could shift transmission cycles to other urban birds such as cardinals [w17]. Crows were generally not seropositive or only seropositive for a very short time because they died quickly. Birds (cardinals) that maintained a high seroprevalence rate, coupled with a much lower death rate from a WNV infection were the ones to monitor [08b]. [In 2013 dead birds are no longer monitored.]

Still camped in **Illinois**, 5,236 birds were sampled for WNV antibodies from 2001 through 2004. In general, birds breeding or born in the state were more likely to have antibodies than migratory birds. Also, the seroprevalence of adults (12%) was over twice as high as in juveniles (5%). Because of this difference, juveniles may provide a better index of annual WNV activity in an area. Overall, birds with a high seroprevalence for WNV were – breeders throughout the year, open cup nesters, and found in cities close to humans. The top four seropositive birds in **Illinois** –

(1) Mourning Dove 38% (n 97)
(2) Northern Cardinal 25% (n 389)

(3) American Robin 15% (n 341)
(4) House Sparrow 10% (n 1,210)

However, the feeding habits of the main vector *Culex pipiens*, the persistence and strength of viremia in birds, and the breeding ecology of birds all confounded the issues for reporting and understanding WNV maintenance and transmission 08b.

In east-central **Illinois**, 156 live crows were captured starting in February 2002. Each crow was banded, sexed, aged and painted across the tail for ease of identification at a distance. For a subset, radio-transmitters of 2–3 grams with a 6-month life span were usually attached to the tail. From May–October, 39 crows carried radio-transmitters. The final outcome of 11 crows was unknown. For the remaining 28 crows, 19 were found dead and tested positive for WNV (68%). When natural causes of death over a year were included, the annual survival rate for crows was about 18% in this local study. This was high, since 72% of the 39 crows were hatch-year (HY) birds, which typically experience a naturally high death rate. Most crows died from 16 August until 6 September, which coincided with the highest rate of WNV-positive pools of mosquitoes. However, one hatch-year (HY) crow tested positive for WNV on 9 July but did not die until 3 September 2002, when it also tested positive for the virus y09. Could this young crow have received antibodies passively from its mother?

Researchers monitored the movements and habitats of crows during the summer when WNV infections in the populations were most likely to happen. They found infected crows did not roost or feed normally. Some birds were on the ground and easily approached. One crow was perched in a tree with one eye closed. Usually, these birds were found dead the next day y11. There was no great difference in the dying rate between the sexes, or for all three age groups from WNV. Generally, crows began dying from WNV in July y10.

In a southwest suburb of **Chicago**, mosquitoes were collected outdoors over the summer. WNV was detected in 227 pools (19%) in 2005, and 12% of 205 pools in 2006. Most were *Culex* spp. Using mist nets, 1,407 birds of 57 species were captured in 2005 and 1,479 birds of 63 species in 2006 over the summer. The most abundant seropositive hatch-year (HY) birds in 2005 were –

(1) Northern Cardinal 71%
(2) Gray Catbird 36%
(3) House Sparrow 21%
(4) American Robin 11%

In 2006, there was a change in seropositive hatch-year (HY) birds –

(1) Northern Cardinal 14%
(2) American Robin 4%
(3) House Sparrow, less than 1%

In spite of these changes, young-of-the-year (HY) birds had a role as amplifying hosts h16.

A sample was taken of nestling birds and mosquitoes in the same area of **Chicago**. Nestling corvids were not sampled. A sample of 194 nestlings from twelve species were obtained in 2006 and 2007 from 61 nests. Open cup nesting species were mostly American Robins and Red-

AMERICAN CROWS In June after leaving their nest, vulnerable fledglings spend several days and nights in trees where they are fed by the parents

winged Blackbirds. From the 12 species sampled, only 2 tested positive, a 10-day-old Mourning Dove (with a low antibody titre), and an 8-day-old House Wren. This suggested nestlings do not have a role in WNV amplification and transmission in Chicago l73.

In Ithaca **New York**, researchers worked with a marked population of American Crows. Data gathered before and after the arrival of WNV indicated the annual mortality of juvenile crows from 1990–1999 was 14% and adults 3%. In 2002 and 2003, years of high mortality from WNV, 50% and 48% of juveniles died, while 29% and 35% of adult crows died respectively. Twenty-two of 23 families lost at least one member and 18 lost more than one member. Nine lost one breeder, and in 6 families both breeders vanished. One family was untouched by the disease. This level of social disruption meant 7 of the 23 families no longer held territories. These vacant territories were slowly filled over the next few years by helpers budding territories from adjacent families c70. Budding is "a former nonbreeder attracting a mate and settling in part of the territory on which it had been an auxiliary" 39w.

In the cool, wet season of 2004, there were no known deaths from WNV in the Ithaca population of crows c70. Surprisingly, for the two years 2003 and 2004, there were no significant changes in family size, nor was there any significant difference in average age of breeders or auxiliaries among the years 2001–2005. The auxiliaries were a built-in buffering system for cooperative breeders. The year 2004 however, revealed the lowest percentage (64%) of families with 3 or more members over the breeding season compared to (91%) in 2001. Social changes were slow and included – female budding, merging families, and adopting a helper. Five cases of budding occurred in 2004 after two harsh years of deaths from WN fever. None of the vacant territories were filled by a new pair of breeders unknown to the researchers c70.

Fledgling crows (75) from 33 extended families were tested for antibodies to the WNV antigen. No maternal antibodies were detected. Perhaps the maternal antibodies were short-lived and not passed on to nestling crows before they fledged, or the breeding females did not have antibodies to WNV. It appears each breeding season ends with fresh young crows susceptible to an infection from the WNV p18.

In **Maryland** and **Washington DC**, at 5 sites

The dead crow data (DCD) were analyzed using the Space-Time Autoregression Moving Average (STARMA) model, which can be written:

$$\mathbf{Z}(t) = \sum_{k=1}^{p} \sum_{l=0} \phi_{kl} \mathbf{W}^{(l)} \mathbf{Z}(t-k) - \sum_{k=1}^{q} \sum_{l=0}^{s} \theta_{kl} \mathbf{W}^{(l)} \varepsilon(t-k) + \varepsilon(t) \qquad (1)$$

Crows are leading avian biologists into areas of research where they have not previously traveled l27

from May to September 2004, field data were collected on bird abundance and blood, along with mosquito identification, abundance and blood. *Culex pipiens* accounted for slightly more than 90% of the collected mosquitoes k65.

It soon became apparent that mosquitoes of the *Culex pipiens* complex in North America were hybrids not restricted to a particular type of host, but took bloodmeals from both birds and humans. This less selective behavior may have lead to the rapid spread and severity of the disease f49. Vegetative cover and age of housing were important indicators of WNV risk in Chicago **Illinois** 34r.

GIS, a Geographic Information System, is based on computer analysis and the display of geographic information in layers. GIS can visualize data using maps and reports to reveal relationships, patterns, and trends. By plotting the locations of dead crows reported by the public, GIS might be helpful in recording the spread of WNV. To be of use in tracking cases of WNV in animals (man included) an initial system combined real-time surveillance, real-time web GIS, and open GIS. Monitoring dead birds helped to launch the control of mosquitoes in certain areas s76.

Another method was the Space-Time AutoRegression Moving Average (STARMA) that was used as a model to analyse the spread of WNV in the metro Detroit **Michigan** area in 2002. The main use of the model was to characterise previous outbreaks by identifying what governed the space-time spread of the disease. It did not work in real time, but almost. The Dead Crow Data (DCD) was attained by recording the address and number of dead crows at each location. The 1,807 reports of dead crows were organized by latitude, longitude, and date for a 28-week period in the warm season l27. (**equation above**)

It was suggested the crows became infected where they roosted, and over the summer they didn't travel long distances. Such movements didn't spread the disease, but due to their high viral loads (viremia), crows might amplify the disease locally. At the same time, some crows may travel a fair distance and start a new local outbreak, which may not be detected by the above analysis. However, local epidemics might be contained by spraying local mosquitoes.

Stalled in Detroit, up to 70% of the dead metro crow population was infected during the 2002 WN season. If many crows died within a local area, there would be a reduced population of crows to be infected the next week, which may lead to an echo effect in the analysis. An autoregressive model was one of a group of linear prediction formulas that attempted to predict the output of a natural system based on previous outputs. "The autoregressive parameters are not rates of spread, but rather relative rates given the overall increase or decrease in WNV" l27.

Across the continent, WNV arrived in **Florida** in mid-2001 when a dead crow was collected in June in Jefferson County. Florida was somewhat

unique since the disease was more concentrated in rural areas of the panhandle and keys. The central part of the state was relatively free of WNV. As in other states, dead crows, American and Fish, along with chickens were the best early warning signs in advance of human cases of WNV. At this latitude, positive wild birds, chickens, horses and mosquito pools were collected in mid- to late December 2001 [23b].

WNV was first isolated in mosquitoes from southern **California** in 2003. In the summer of 2004 the disease was widespread throughout the state. The Breeding Bird Survey data from 1994–2005 throughout California was analyzed. They found declines in four corvid species. For American Crows between 2004 and '05, there was a 70% drop. Corvid deaths by WN fever could register a BBS decline in a region / state [k94].

Remaining in southern **California**, around San Diego during late October 2003, of 57 dead birds positive for WNV, 47 (83%) were American Crows [r40]. The role of corvids was checked (2004) in three different environments. Of 933 reported dead birds, 810 (87%) were American Crows. Where clusters of crows died from WN fever, their high abundance was located in the midst of a dense human population, such as the Los Angeles area. Where clusters of dead crows were located, 75% of human cases of WNV were found. Presented another way, human cases within areas of dead crow clusters were 6 per 100,000, and outside areas of dead crow clusters, 1.4 per 100,000 people. Overall, small urban crow roosts in the summer served as amplification sites since crows and Western Scrub-Jays become lethargic and developed high viremias past the 10^9 plaque-forming units / ml (PFU) prior to death. When the birds were fed upon prior to dying, the newly infected mosquitoes spread the disease to other birds and humans. In conclusion, it may be a less virulent strain of the virus that allowed crows to coexist with the disease, since not enough American Crows developed high resistance to coexist with the virus [r41].

Year-round transmission of WNV

Still in **California**, 2,167 dead birds from 151 species were tested from November to March in 2003–'05. Of these, 6% (132) were positive for WNV. Tested American Crows (572) revealed 11% positive. None of the sentinel chickens, but one pool of mosquitoes was positive. In parts of California, temperatures were warm (14 ºC) enough over the winter to keep mosquitoes active, hunting, and transmitting WNV. However, many of the levels of infection were quite low [r42].

A White Admiral; mid-June in **Winnipeg**

As early as the year 2000, overwintering virus-infected *Culex* mosquitoes were found in **New York City** [n03]. In February 2000, a Red-tailed Hawk died in Westchester County **New York** from the virus. Perhaps the hawk ate infected prey. Since American Crows also feed on dead animals, they may acquire WNV in the winter from a host-reservoir [g07].

When one thinks one is getting close to understanding American Crows and WNV, a knuckle ball is thrown. In Poughkeepsie **New York**, dead crows were found at an overwinter roost in 2004. This was normal, since a small number die each week; mostly juveniles. A collection of these bodies was tested for WNV using standard laboratory tests. From 10 February to 29 March 2005, 98 crow carcasses were gathered from the roost and tested [d27]. Of these, 13% were positive for WNV. The 13 positive crows had –

(1) low body weights 85%
(2) an enlarged spleen 23%
(3) an enlarged liver 31%

These crows were tested 3 different ways

to confirm death by WNV. During the epizootic, temperatures averaged less than 10 ºC within a ranged of about –12 to +17 ºC.

The 85 WNV-negative crows died from –

(1) traumatic injuries 52%
(2) predation 16%
(3) avian pox 14%
(4) pneumonia 12%
(5) poisoning 6%

Field workers reported no mosquito activity and searching for mosquito hibernacula proved futile in New York. From 45 samples of crow shit, 3 (7%) were positive for WNV [d27]. What was the quantity of WNV in shit from experimentally infected American and Fish Crows? For 10 American Crows, the peak fecal titers ranged from $10^{3.5}$ – $10^{8.8}$ PFU / grams and for Fish Crows $10^{2.3}$ – $10^{6.4}$ PFU / grams. These values could lead to a direct transmission of WNV. People handling sick and dead crows should be cautious [k72].

Crows perched on lower branches at a roost receive splashes of shit from overhead. Through preening, it is possible the virus in their shit was transmitted between crows. But how did crows become infected so late in the season and then die at their roost? Or perhaps dead crows collected toward the end of March, as the crows at the roost dispersed for the summer nesting season, became infected in March and carried the virus from the roost and started a new cycle several kilometers away. One dead crow collected on 7 March 2005 was positive for WNV by one test only [d27].

Chronic infection in crows seems unlikely since they die within a week after being infected with the virus. However, radio-tagged, infected crows have flown up to 4 km per night before they died [w19]. At a roost, it seemed probable that crow-to-crow transmission was responsible, via crow shit or from WNV-positive lice (*Philopterus* spp.) collected from four WNV-positive crows. Another possibility – crows may eat fresh meat such as House Sparrows infected with WNV.

There was year-round transmission of WNV along the Gulf Coast in **Louisiana** and **Texas**. But the number of dead birds collected and tested was much lower than during the warm months. The rates for WNV-positive birds was 0.7–14% from November 2003 through March 2004 when only 2 mosquito pools tested positive. Even so, this may lead to spring migrants carrying the disease northward. Overall, from Janu-

Gravity-inspired water over smooth rocks in mid-April

A gusty west wind forced a crow to keep low on the street light. Looking away from the camera, the neck feathers were brushed aside revealing a gray crow beneath the thin dark surface

ary 2003–March 2004 (15 months) 70% of the American Crows (n 23) were infected with WNV in Harris County, Texas t28.

Certain factors were associated with dead WNV-positive crows in Tompkins County **New York** from 2000–2008. "The risk of a crow carcass testing WNV positive varied with age, season of the year, and ecological area where the carcass was found. Crows more than 1-year-old were four times more likely to be WNV positive in comparison to birds that were less than 1 year of age. It was three times more likely to find WNV positive carcasses in residential areas in comparison to rural areas. The risk of testing WNV positive did not vary by sex of the crow carcass" d28.

Towards the end of the first decade of the new millennium, some of the surveillance shifted away from gathering and testing dead birds. For example, The City of **Hamilton Ontario's** website on WNV announced– "Effective 2009, Hamilton will no longer be testing birds for West Nile Virus. Dead bird testing is no longer required as an early indicator of West Nile Virus in Ontario because information collected over the past few years across the province has confirmed when and where the virus will most likely appear. Effective 2010, we will no longer be tracking dead birds as we have found the data does not show us any trends and it has not been a good predictor of increased West Nile virus activity in our area."

A summary of the disease in the first couple of years in the United States, and its impact on birds was published in a comprehensive review of the consequences of WNV on wildlife 01m, 03m. Additional consequences of WNV, based on reduced avian populations, may include changes in seed dispersal, predation, scavenging, regulation of insects, and a reduction in recreational bird-watching l04.

WNV detection

During the early spread of the virus, one of the main problems was how to quickly and cheaply determine that a crow or other animal died from WN fever. Several methods were tried –

(1) ELISA Enzyme-linked immunosorbent assay uses antibodies and color change to detect and identify the WNV antigen from naturally infected American Crows. Testing crows for WNV is difficult because of the presence of other similar viruses, such as Saint Louis encephalitis virus (SLEV) in the same geographic area. But this immunoassay has adequate sensitivity and can distinguish WNV from SLEV. The test uses a reliable, inexpensive and rapid blocking assay to detect WNV in birds 27b. The methodology

is relatively easy and is less expensive than the TaqMan assay.

(2) TaqMan RT-PCR (reverse transcription-polymerase chain reaction RNA assay) detects and quantifies WNV RNA of lineage 1 and lineage 2 (wiki).

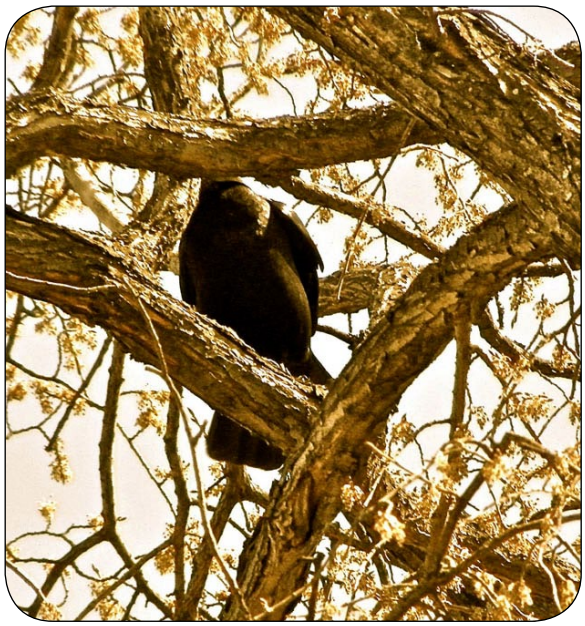
(3) IHC The immunohistochemistry (IHC) staining technique is used with further confirmation by the traditional RT-PCR. IHC is an inexpensive, although slower test than RT-PCR. It is also less hazardous, based on a formalin-fixed virus, and multiple organs can be screened at the same time. The fixed tissue may be examined visually for structural damage w48.

For example 85 American Crows were found dead in **Michigan** in the summer of 2001. Kidney, liver, lung, spleen and small intestine tissues were formalin-fixed and used to detect WNV. A polyclonal antibody proved to be a highly sensitive (100%) diagnostic test compared to the monoclonal antibody-based IHC staining at 72% s96.

(4) IFA relies on an indirect fluorescent antibody (IFA) to detect WNV. Various tissues of dead crows in **Connecticut** exhibited high sensitivities. The diagnostic specificity was liver 69%, kidney 95%, and spleen 96%. The brain and heart were unsuitable because of excessive background. The IFA is a useful, rapid and practical way to screen for WNV f50.

(5) VecTest A rapid wicking assay test in a field kit gives results in less than 20 minutes. It was tried on dead crows in **Illinois**. The VecTest was originally developed to test for the virus in mosquitoes. Eventually, it was discovered that cloacal and oral swabs from dead American Crows gave good results, with oral swabs slightly more sensitive than cloacal swabs for infectious particles of virions k99.

Using diluted cloacal, salivary scrapings and some internal tissues, 20 dead crows were tested within 36–72 hours after dying. From other back-up tests, 17 of 20 (85%) of the VecTest results were confirmed. Further developments increased the test's usefulness, including the length of the postmortem period for which it worked on dead



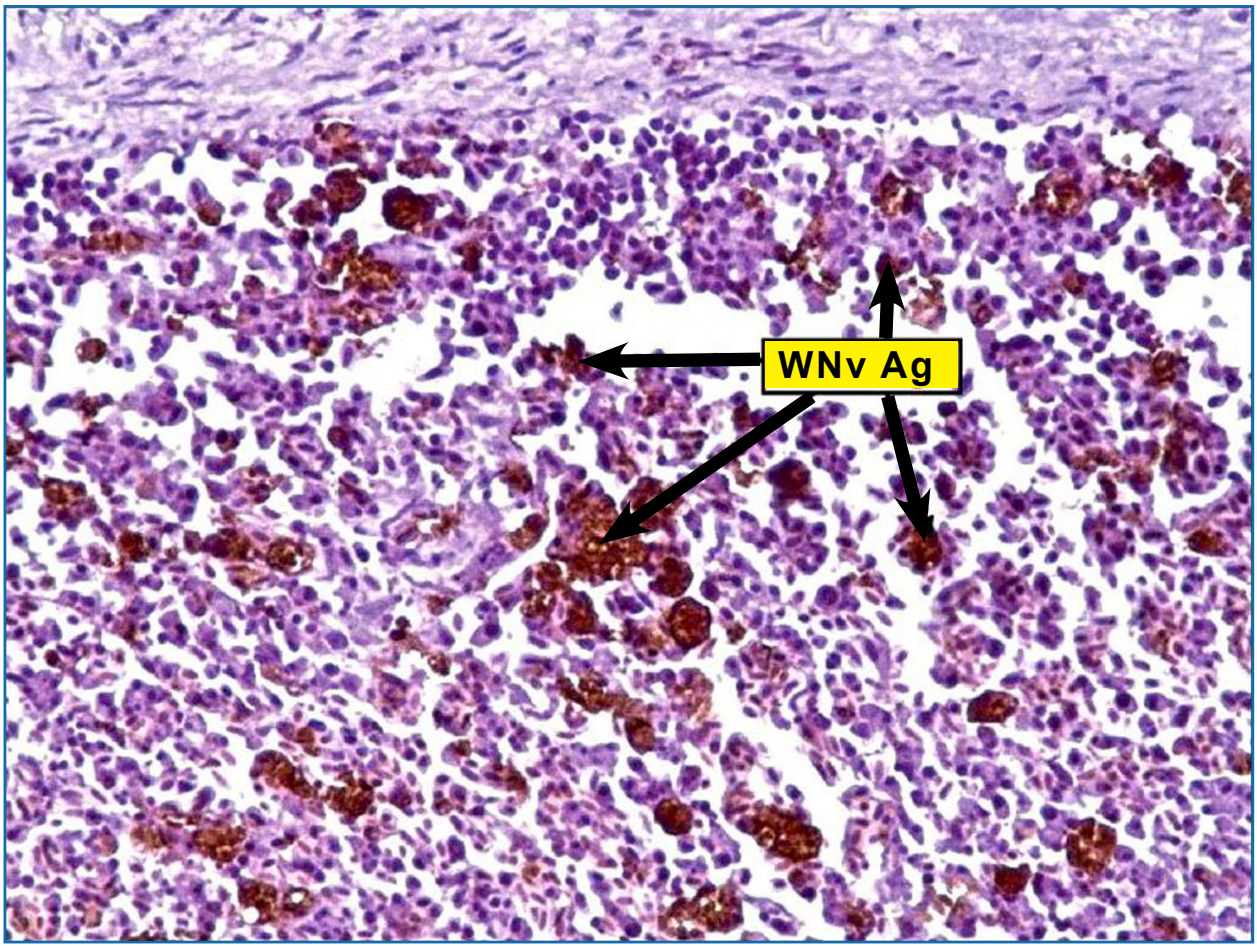
An American Elm in bloom around an American Crow

crows y08. When 31 Blue Jays and 9 American Crows were tested for WNV, the VecTest proved to be 100% accurate when it was confirmed by the PCR test. h78.

(6) RAMP The antigen-capture assay Rapid Analyte Measurement Platform (RAMP) test had over a 95% specificity and was sensitive (64%) to oral swabs from America Crows infected with WNV particles p01.

There exists pathological and histological findings of the crow's internal organs in relation to WNV infection. In 2000, a crow's brain was shown to be the most sensitive of its organs for detecting WNV p04. All the dissecting, however, was time consuming and expensive since thousands of dead crows patiently waited in line for an autopsy. Later, in a 2011 article, there was a re-examination of the occurrence of antigenic distribution of West Nile virus in tissues of 9 organs in 31 dead infected crows collected in the wild from reports by the public. The levels of distribution using IHC technique –

(1) Spleen 100% **(6)** Gonads 70%



AMERICAN CROW'S SPLEEN – staining was diffuse and WNV antigen-stained cells were reticulendothelial cells s18. (Reticulendothelial cells play a role in inflammation and immunity and are found in the spleen and other organs.), © Journal of Global Infectious Diseases

(2) Duodenum 95%
(3) Kidney 95%
(4) Liver 95%
(5) Lung 92%
(7) Heart 63%
(8) Pancreas 63%
(9) Brain 37%

The use of pieces of liver, spleen, kidney, lung and intestine increased the accuracy of the results. In the spleen, the reticuloendothelial cells were stained s18. (**above**)

Allowing infected mosquitoes to bite 25 bird species revealed some dynamics of the transmission. Eight of the bird species died. The American Crow was among the five most impacted species. Cloacal shedding of WNV was noted for 71% of 24 species, and oral shedding in 86% of 14 species of birds. WNV was found in the tissues of 16 surviving birds. Orally-acquired infection of WNV was confirmed in an American Crow. Bleeding from the mouth or cloaca was observed in a small number of crows that died. Also, some American Crows were infected by contact with an infected cage mate. The viremia profiles were similar in crows that contacted the disease all 3 ways 01k.

American Robins, a widespread species, do not die from WNV, but are infectious for 4–5 days. This made them a reservoir for the transmission by those mosquitoes that preferred to feed on robins 24w. Mosquitoes were collected in **Maryland** and **Washington DC**, and although American Robins comprised only about 5% of the local bird population, they accounted for 43% (24–71%) of the bloodmeals identified in *Culex* mosquitoes

from May to August. Mosquitoes fed on 8 bird species preferentially at various times of the season and not relative to any bird's abundance k66.

In **North Dakota**, wild Red-winged Blackbirds were tested for their prevalences of WNV antibodies in 2003 and 2004. The two annual peaks were 22% in August 2003 and 18% in July 2004. With millions of Red-wing Blackbirds in North America, they may contribute to the spread of the virus when they migrate north and south. It is not known how the virus affects the health of these blackbirds and in what numbers. Like crows, Redwings migrate during the day and roost at night. During the night they may be bitten by mosquitoes, and if their viremia was high enough, the mosquitoes may be infected, which would spread the disease locally 88s.

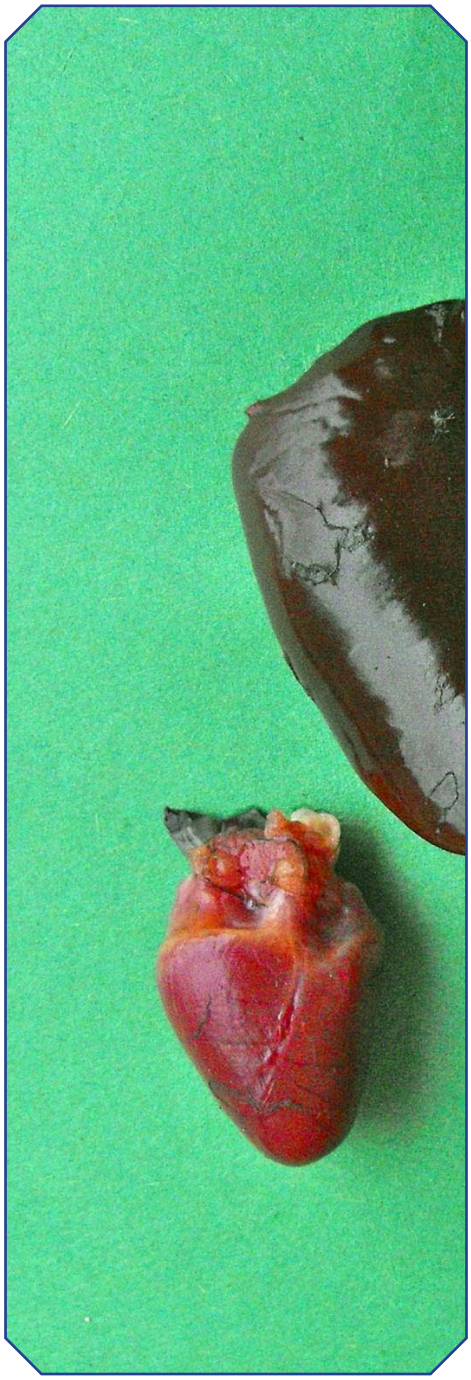
After being experimentally infected, 31 American Crows were examined for two strains of WNV using three tests –

(1) VecTest WNV rapid antigen assay
(2) TaqMan RT-PCR
(3) Vero cell plaque assay for detecting virions.
Tests 1 and 2 were about equal in detecting WNV, and more sensitive than 3, the plaque assay test.

None of the tests were 100% accurate all the time. The VecTest had a 90–100% accuracy level up to 4 days postmortem.

Using a combination of cloacal and oral (nasopharyngeal) swabs from dead crows, the swabs should be tested within 48 hours after death. But carcasses could be tested no matter how old as long as it was possible to take an oral swab. Swabs collected in the field could be stored at room temperature in cryovials for up to 48 hours. They still gave a reliable result for WNV antigen using the VecTest p05. In **Colorado**, oral swabs of American Crows had an 83% positive sensitivity n12. The VecTest was adequate, but not perfect in detecting WNV-positive birds –

(1) American Crow 87%
(2) Blue Jay 80%
(3) House Sparrow 76%



AMERICAN CROW'S heart and part of its much larger liver. Tissues from both organs were often tested to verify WNV as the cause of death

AMERICAN CROWS Fledglings have no acquired immunity against West Nile Virus; the first week of June in Winnipeg

For more accuracy tissue from kidneys of crows reduced the number of false-negatives [67s].

Crows (109) were collected in **Manitoba** and 255 crows in **Ontario** in the early 2000s to check the precision of the VecTest antigen-capture assay to detect WNV in dead crows from the field. The sensitivity and specificity of the VecTest were checked mainly from oral swabs, which were more sensitive than cloacal swabs. In Manitoba, the sensitivity and specificity were 84% and 94% respectively. In Ontario, the results were similar, 83% and 96%. It was concluded the 15 minute, easily executed and relatively cheap test was useful in the field for surveillance of WNV. Regardless of storage conditions of the swabbed samples, VecTest performed well at viral concentrations greater than 4×10^6 for up to 7 days, but never at lower titers such as 4×10^4 PFU / ml. Some of the early seasonal infections could be missed. Early in the season, the real-time RT-PCR Taq-Man assay was more sensitive and at times a suitable test to confirm the presence of WNV prior to notification of the public about the appearance of the disease. The VecTest did not work well with raptors. It had a sensitivity of only 47% from oral swabs on 27 raptors of several species [l46].

Feather pulp isolated from large wing or tail feathers of crows during their summer molt gave a 77% positive rate for WNV. This compared to 43% for kidney and spleen pools, and 38% for cloacal swabs alone. It appears feather pulp contains more virions resulting in a higher reading [d56].

Fully grown, but nonvascular feathers were obtained from dead and living birds. Feathers from corvids provided the highest sensitivity of WNV detection (64%) from naturally-infected carcasses. Testing several feathers increased the odds of detecting WNV. Working with nonvascular feathers probably reduced the risk to humans, and could be used in remote areas n14.

In **Quebec,** between 1990 and 2005, census numbers were gathered annually from Studies of Bird Populations (SBP). The data was divided into urban and non-urban areas, by month and by year. In urban areas before the arrival of WNV, there was a numerical population cycle with a periodicity of 36 months. This 3-year cycle may have resulted from a bisected 6-year cycle. The cycle for the American Crow might be due to –

(1) the average age at which crows are mature enough to breed
(2) life expectancy
(3) other factors

After the arrival in 2002 of WNV in Quebec, there was a major fluctuation in the number of crows six months later in 2003, in both rural and urban areas. Slightly smaller fluctuations took place in 2004 and 2005. Thereafter, a normal dynamics returned to the crow population l79.

In **Quebec**, the 2005 WNV surveillance year from 5 June to 17 September was examined. Only 21% of the 332 crow carcasses submitted were positive for WNV. Age of the birds, and time of year were two important variables explaining baseline mortality –

(1) the probability that a carcass tested positive for WNV increased with the age of the bird and as summer progressed
(2) WNV-positive carcasses had a lower body

AMERICAN CROWS On a wide branch the lower fledgling does not have to grasp as tightly as the upper fledgling does to the thin Cottonwood twig

condition index than WNV-negative carcasses

In conclusion, the initial seasonal deaths of American Crows in the early part of the summer were mostly due to the usual mortality factors among juvenile crows after fledging, rather than WNV which seems to strike that age group less often. Because of this, crows may not be the best species to indicate the early start of WNV activity regarding human infection. Data also suggested the second-year (SY or AHY) yearling American Crows were important vectors in propagating WNV by their movements about the urban landscape in the summer [80].

In the province of **Quebec** a working model, eventually based on field data in the mid-2000s, described the population dynamics between two main species in the WNV theatre – the American Crow and mosquitoes of the *Culex* species. The model, after addressing variable inputs, could be a predictive tool for a summer's outbreak of WN fever based on weather and other specifics. It indicated when to apply larvicides and mosquito repellent as we ventured outdoors to study crows [41b].

Adjacent counties with and without human cases of WNV were studied in the early 2000s in the northeastern United States in relation to avian (viral host) diversity (the dilution effect). From electronic models, "subtle differences in avian diversity between neighboring counties helps buffer humans against WNV infection. Overall, avian community structure can explain approximately 50% of the variation in human WNV incidence." It was concluded the protection of biodiversity was an important consideration in public health and safety [95s]. This explains why a reduction in biodiversity is the goal of some people on this tiny planet.

The Center for Disease Control (CDC) at Fort Collins **Colorado**, is a cache of information on the web. As well, the 2010 annual report from the Canadian Cooperative Wildlife Health Center (CCWHC) indicated 262 dead crows were received – 255 were tested and 15 (6%) were positive for West Nile virus.

Field corn hangs when ripe. After the harvest crows dine on what remains in the fields

Mosquito vectors

In North America, 62 species of mosquitoes tested positive for WNV infection (CDC 2007). However, in any one locality, only a few species are likely to be suitable vectors capable of transmitting the disease, and only a fraction of the mosquitoes feeding on an infected bird will themselves become infected [01k]. An infected mosquito is not always infectious (able to pass on the virus) during a future feeding [k67]. *Culex* spp of mosquitoes get a bloodmeal every 6–21 days and can live from 10–65 days in captivity depending on the ambient temperature [29s].

Generally, WNV is maintained through a bird–mosquito enzootic cycle involving multiple hosts and vectors. Temperature, feeding habits and abundance determine how potent mosquitoes are in spreading a viral disease. Laboratory vector competency is the ability of a mosquito to

become infected and then transmit the virus to a vertebrate host within a laboratory. *Culex* species are usually competent vectors, *Culex tarsalis* is highly competent. The pool-breeding *Aedes* and *Ochlerotatus* species are relatively inefficient vectors of the disease in a laboratory. **"**In determining the potential for a mosquito species to become involved in transmitting WNV, it is necessary to consider not only its laboratory vector competence but also its abundance, host-feeding preference, involvement with other viruses with similar transmission cycles, and whether WNV has been isolated from this species under natural conditions**"** t84.

In 2000, during the second year after the arrival of the introduced virus, a summary showed WNV was detected in 515 mosquito pools in 38 counties in five states. *Culex* species were found in 89% of the infected pools m31.

Temperature helps to determine the virulence of infected mosquitoes. A hot summer can hasten the spread of the disease. Bearing the virulent NY99 strain of WNV, *Culex pipiens* mosquitoes were exposed to a variety of temperature regimes. In an incubation environment of 30 ºC, some infected mosquitoes passed on the virus only 4 days after ingesting an infected bloodmeal. After 12 or more days, over 90% of mosquitoes transmitted the infection through a bite. When held at 18 ºC, after 28 days less than 30% of mosquitoes transmitted a WNV infection. The competency decreased with a decrease in the surrounding temperature. A cool summer greatly reduces the numbers of WNV cases in birds and people d57.

For example, in 2011 Winnipeg **Manitoba** experienced a cool and dry summer with almost no mosquitoes in and beyond the city, which led to zero cases of WNV recorded in crows, horses, people and mosquitoes (online). A very rare entomological summer according to the people that have spent their lives in Winnipeg. In **Manitoba**, dead crows are no longer needed to track the disease in the province. Adult and larval mosquito sampling and testing in addition to factors such as temperature, etc. are used to assess the risk of West Nile virus exposure to people. Abnormal swings in temperature, coupled with a genetic shift in WNV from NY99 to WN02 combined to change the distribution and intensity of transmission of this virus k68.

A mosquito bite

What happens when an infected mosquito bites a bird? First of all, a mosquito takes a bloodmeal from an infected bird and becomes infected herself. The West Nile virus replicates itself in the mosquito's gut and salivary glands, and is passed along with salivary fluid when that mosquito bites another vertebrate m32.

The insect's salivary proteins can impair the anti-viral immune response in a bird. The immediate environment around the bite suppresses the immune system. T- and B-cell populations are killed or experience lower cell division rates. This can increase the strength of the infection and alter the rate of survival of the virus and bird s38.

Various species of mosquitoes around the **New York City** area were collected and tested in 2000, the year after the advent of WNV in the city. They were allowed to bite previously infected chickens with a viremia of $10^{7.2}$ PFU / ml. The WNV used to infect the chickens was recovered from a dead crow. All 10 species of mosquitoes

were susceptible to infection and almost all were able to transmit the virus during their next bite t82. Four species of mosquitoes were tested in the lab. *Culex pipiens* was probably the main vector in the New York City area during the initial outbreak in 1999 t81.

In a southwest Chicago **Illinois** suburb, a few species of super-spreaders (American Robin, Blue Jay [a corvid] and the House Finch) had the dual function of being a reservoir for the virus, and an attractive host for feeding mosquitoes, particularly *Culex pipiens*. When the mosquito started to feed on humans, the transmission of West Nile virus was possible. *Culex pipiens* fed on 25 species of birds in the Chicago area, but not all of the bird species were viremic enough to infect the mosquito with WNV. Based on the relative abundance of avian species in a local area, robins were slightly overused by the feeding mosquitoes, and several other species were underused. In addition to birds, several mammals also accounted for 17% of the feeding by *Culex pipiens*, with humans taking up 16% of the 17%. It was estimated 66% of WNV-infectious *C pipiens* were developed by feeding on only a few avian super hosts h17.

Culex tarsalis

Since I studied crows in **Manitoba**, I will outline several aspects of the life of *Culex tarsalis*, the mosquito found in western North America and tested for WNV in this province. From the Rutgers New Jersey Agricultural Experimental Station Center for Vector Biology, *Cx tarsalis* is –

(1) An important vector for the maintenance, amplification and epidemic transmission of several viruses
(2) An abundant summer species that is scarce east of the Mississippi River, but active over the winter in southern California
(3) Easily distinguished as adults from other *Culex* species by white bands on parts of the body
(4) Propagated by rafts of about 200 eggs deposited on sun-lit, ephemeral water pools often surrounded by vegetation. Larvae tolerate alkaline, fresh and saline waters, but not excessive organic pollution
(5) An early colonizer of newly formed pools Larval development takes 7–25 days depending on food and temperature; usually less than 5% survive due to predation
(6) An egg layer 4–5 days after emergence by some females. Their eggs mature without recourse to a bloodmeal. In the north, females overwinter in facultative diapause and need a bloodmeal to produce their first eggs in the spring
(7) A feeder on birds shortly after sunset in the spring. In summer, people, horses, rabbits and cattle are fed upon. Host seeking flights may reach 27 kilometers, averaging about 90 m a day from rural sites along rivers and crop fields

Compton Tortoise Shell feeding at a male willow catkin in May

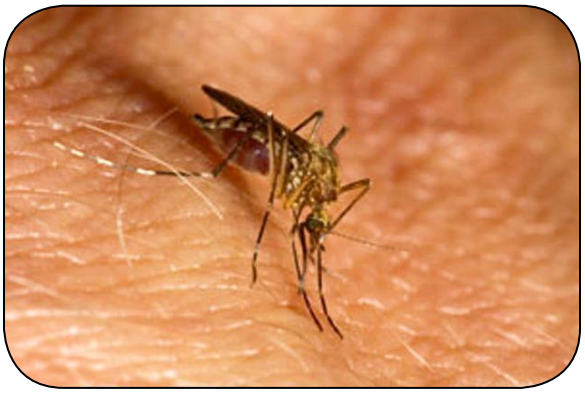
Mosquitoes remain infective for life. *C tarsalis* breeds in agricultural areas and travels a few kilometers into urban areas to hunt. Wind may hasten or hinder the travel of infected mosquitoes 16w.

Culex tarsalis is found from the Mississippi River to the west coast, south into Mexico and north into parts of Canada, including **Manitoba** d10. Based on this range, a study was initiated on its genetic data and the flow of WNV westward from the east coast. In 2002, WNV had reached the Mississippi River, the eastern edge of the range of *C tarsalis*. From there, by the end of 2002, it had invaded the Great Plains. In 2003 the virus arrived in the southwest and began to cross the Rockies. By 2004 the virus traveled northward through **California**. There appeared to be few barriers to its gene flow across the three genetic clusters in the mosquito's population v08.

An American Crow tilts its head for a better look

Feeding by mosquitoes

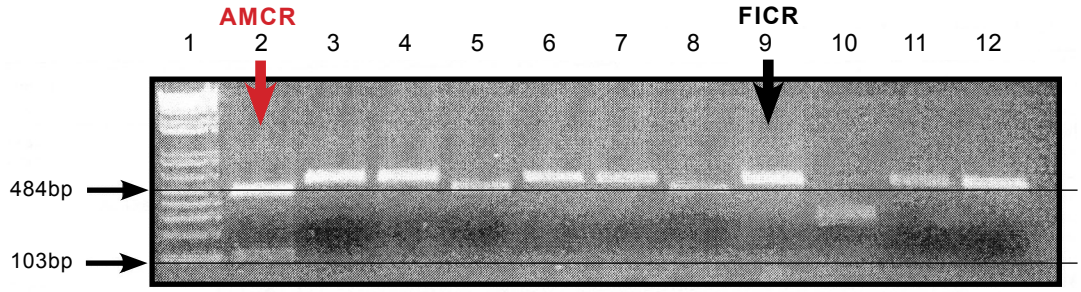
How often do mosquitoes land on American Robins in **Maryland** and **Washington DC**. Using high resolution infrared cameras during nesting, the birds were monitored day and night. The mosquitoes could only be detected on landing. It was not possible to know if they fed on the adults or nestlings. Over 99% of mosquito observations at nests fell between 8 PM and 6 AM. The average number of landing per night on adults brooding nestlings was 123 and on nestlings 37. Brooding young nestlings reduced the number of mosquitoes landing on them each night. The brooding adult robins tucked their bills into feathers which reduced the exposed skin on their heads. Nestlings (165) were swabbed at 21 nests over the summer and all were negative for WNV g67.



West Nile virus is dependent on mosquitoes and birds for its survival; mammals are dead-end hosts. Image without source from www.west-nile-virus-prevention.com/west-nile-virus-history.html

Other people looked at the relationships between birds, mosquitoes and humans in North America. In the northeastern part of the USA, when American Robins began to migrate and disperse in the late summer, *Culex pipiens* shifted its feeding to humans, and that was when the number of infections in humans increased. The same trend was found for the mosquito *Culex tarsalis* in the western part of North America k65.

Which birds were the hosts that provided the bloodmeals in mosquitoes? Primers (a molecule that serves as a starting material for a polymerization process) for the cytochrome b gene separates avian and mammalian bloodmeals. The avian orders, columbiformes, falconiformes, galliformes and passeriformes could also be identified. And American Crows were identified from the other passers by using restriction enzyme digestion of host mitochondrial DNA. Mosquitoes imbibe about 30 µl of blood per feeding. Mitochondrial DNA, especially genes for cytochrome b, are commonly used to determine phyloge-

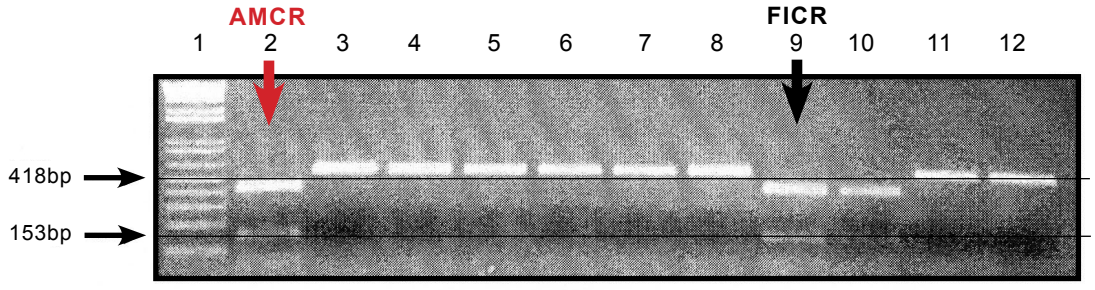


232. Restriction digest using *Bam*H I on cytochrome b DNA from the following birds: lane **1**, 1-kb plus ladder; **lane 2 American Crow;** lane **3** American Goldfinch; **4** American Robin; **5** Brown-headed Cowbird; **6** Blue Jay; **7** Common Grackle; **8** European Startling; **9** Fish Crow; **10** Gray Catbird; **11** House Sparrow; **12** Northern Mockingbird; bp = base pairs ^{n20}, © Entomological Society of America

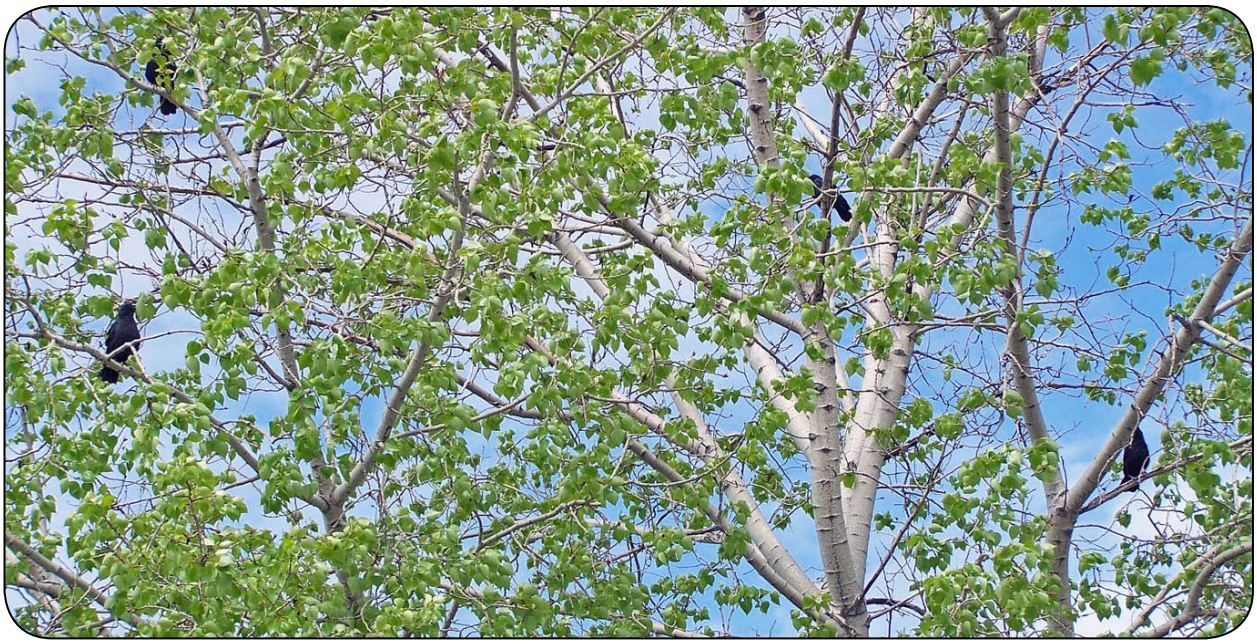
netic relationships between organisms due to its sequence variability. It is considered most useful in determining relationships within families and genera. The segments of cytochrome b gene were amplified, then mapped for restriction sites. Two restriction sites, *Bam*H I and PfIM I, in combination, were unique for the cytochrome b sequence of the American Crow. Restriction sites were locations on a DNA molecule containing specific sequences of nucleotides, which were recognized by restriction enzymes that may cut the sequence between two nucleotides within its recognition site. Unknown DNA samples were typically run on a gel with a sample of DNA where bands sizes were known along a ladder at the edge. After the sample was run, the unknown fragments were compared with the known ladder fragments to determine the approximate size of the unknown DNA bands.

Passeriforme DNA (deoxyribonucleic acid) was amplified in a PCR (polymerase chain reaction) then digested with both *Bam*H I and PfIM I. After electrophoresis, the expected product sizes for the American Crow were 103 bp (base pairs) and 484 bp after digestion with *Bam*H I, and 153 bp and 418 bp after digestion with PfIM I (**Figs. 232 and 232a**). The newly designed primer sets were tested on tissue and blood from 18 species of passeriformes. The American Crow was the only passerine displaying the expected restriction patterns with both enzymes.

Blood from several species of mosquitoes was tested for avian DNA. Most of the *Culex pipiens* (86%) fed on passeriformes. Feeding little on mammals, including humans, may restrict its probability as the vector transferring WNV from birds to people. As to longevity, quail DNA could be detected in *Cx pipiens* for up to 3 days after feeding at 27 ºC. Bloodmeal analysis provided the frequency of feeding by mosquitoes on crows,



232a. Restriction digest using PfIM I on cytochrome b DNA from the following birds: lane **1**, 1-kb plus ladder; **lane 2 American Crow**; lane **3** American Goldfinch; **4** American Robin; **5** Brown-headed Cowbird; **6** Blue Jay; **7** Common Grackle; **8** European Startling; **9** Fish Crow; **10** Gray Catbird; **11** House Sparrow; **12** Northern Mockingbird; bp = base pairs ^{n20}, © Entomological Society of America



Four fledglings well spaced out in Cottonwoods 30 m from their nest in a Colorado Spruce. The nestlings flew to these Cottonwoods each year when they fledged from the same reused nest in the spruce. How often mosquitoes feed on fledglings has not been established

compared to other species of birds n20.

A test was setup to monitor the attraction of *Culex pipiens* to three common urban birds – European Starling, House Sparrow and American Robin. When the birds were placed outdoors in cages, the American Robin was preferred by the mosquito. This attraction to some avian species was probably an inherent characteristic of *Culex pipiens* s85.

Different mosquitoes operate at different height regimes during the night. For example, at Niagara Falls **Ontario**, mosquito traps were of two types **(1)** no lights and baited with CO_2 (Control traps) and **(2)** no lights and baited with cotton swabs of uropygial gland secretions from American Crows (Crow traps). Traps were set at two elevations – about 1.5 and 5 meters. Since *Culex pipiens* and *Cx restuans* were difficult to tell apart, they were grouped in the trials as *Cx pipiens / restuans*. From the 2,482 mosquitoes captured, the most abundant species was *Cx pipiens / restuans* (57%) followed by *Aedes vexans* (23%). Several other species made up the remaining 20%

Of the 1,404 *Cx pipiens / restuans* captured, 78% were caught in the 5 m level traps.

At 1.5 m elevation traps
10% were in the Control traps
12% in the Crow traps

At 5 m elevation traps
32% were caught in Control traps
46% were caught in Crow traps

For the 587 *Aedes vexans* captured, 92% were caught in the 1.5 m level traps.

At 1.5 m elevation traps
48% were in the Control traps
44% were caught in Crow traps

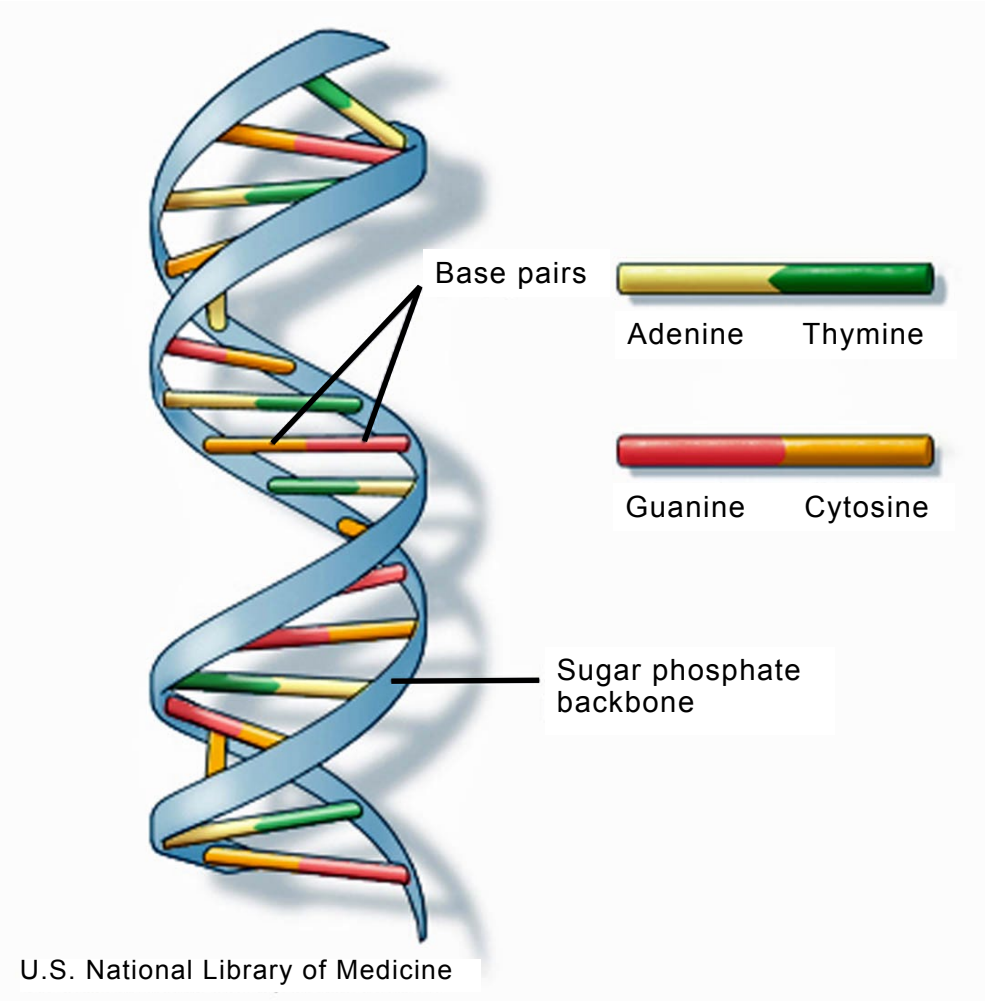
At 5 m elevation traps
2% were in the Control traps

6% were in the Crow traps

When WNV surveillance for a particular mosquito is employed, the setting of traps at the right height for each species gave a better sample of its population. Baiting traps with uropygial gland secretions from the American Crow helped to attract more mosquitoes [37r].

In **Connecticut**, a collection was made of 137,199 mosquitoes of 32 species from June–October 2000. Multiple isolates were collected from only 4 species – *Culex pipiens*, *Cx restuans*, *Cx salinarius* and *Culiseta melanura*, that were thought to be the most important vectors in the transmission cycle of WNV. For these 4 species, the minimum field infection rate (MFIR) per 1,000 mosquitoes ranged from 1.3–77, the lowest in *Cu melanura* and the highest was found in *Cx pipiens* [a41].

Hovering in **Connecticut**, mosquitoes were collected state-wide from June–October 2002–2004. Analysis of their isolated bloodmeals was based on DNA sequences matched to a GenBank, or published results. Three mosquito species and 34 bird species were compared. Blood from an American Crow was found in one bloodmeal of *Culex pipiens*. The top three birds fed upon by the mosquitoes were American Robin, Gray Catbird and House Sparrow. All three species of insects – *Cx pipiens, Cx restuans* and *Cx salinarius* were involved to differing degrees in the transmission process. Eleven mammalian species including humans were fed upon by *Cx pipiens* and *Cx salinarius* [35m].



234. A stylized diagram of a bit of the DNA double helix, © U.S. National Library of Medicine, www.chemguide.co.uk/organicprops/aminoacids/dna1.html (Jan 2013)

Still in **Connecticut**, two mosquito species were sampled in the early 2000s. *Aedes vexans* and *Culiseta melanura* act as secondary vectors for WNV. From bloodmeal analysis of 119 *Ae vexans,* 92% acquired their bloodmeals from mammals (80% White-tailed Deer) and 2.5% from birds. *Cu melanura* fed mainly on birds (90%) and mammals (4%) with the American Robin (23%) the most common source while the American Crow supported only 2% of bloodmeals in this vector [36m].

In Harris County **Texas**, *Culex quinquefasciatus* was the dominant mosquito vector. Analysis indicated it acquired blood from birds (39%); mammals (53%) and a mixture from bird and mammals (8%). The domestic dog was the most utilized host (41%), then the Mourning Dove at 18% and the American Robin at 2.5% [37m].

Along the **Red River Valley** in the northern Great Plains from 2003–'05 during the warm months, 277 birds of 11 passerine species, including the crow, were monitored for WNV antibodies. About 0.1 ml of blood was taken from the wing. The presence of WNV depended on local weather conditions. It was less prevalent in the cool summer of 2004, due to slow vector larval development that resulted in a short transmission season of 51 days compared to 92 days in 2003, an epidemic year. WNV was detected only in *Culex tarsalis*. American Crows had an unnaturally high seroprevalence to WNV, and although the size of the sample was very small, 33% of six American Crows in 2004 and 50% of six crows in 2005 had antibodies. Why did some crows in the Red River Valley survive the viral infection? There was some evidence that passerine immunity to the virus may last longer than one season. All 11 passerine species sampled in 2004 and 2005 had seropositive members. They were infected by mosquitoes in spite of nesting in quite different habitats [b78].

Continuing on an upward wing beat, seroprevalence (WNV-reactive antibodies) in wild American and Fish Crows in central **New Jersey** was followed over each transmission season from 1999 until the end of 2005. The antibody prevalence rate in American Crows ranged from 0–33% in adults (n 1–45) and 0–14% in juveniles (n 1–128). As expected, Fish Crows fared better, with an combined range of 0–54% for adults and juveniles. Overall, the annual median drop in dying for American Crows was about 1.5% each year [r32].

In Seattle **Washington**, over the summers of 2003–'04, landscape and climatic patterns were thought to influence mosquito abundance and behavior. *Culex pipiens* was the most abundant species and its abundance increased with warmer weather. Strangely, rainfall had a less obvious impact on mosquito abundance. The abundance of potential mosquito vectors was highest in the suburbs, city centers, and near small communal summer roosts of American Crows [p27].

In **California**, 10 species of mosquitoes were studied in a laboratory. All became infected with WNV and were competent transmitters to some extent. Four *Culex* species were thought to be major vectors for the transmission and maintenance of the disease in the state [g27]. From Breeding Bird Surveys (BBS), 69% of the routes registered a decline in the Californian population of American Crows from 2004 to 2005. A total of 5,294 crows were tested and 56% were WNV

positive. This was the worst in the 11 years examined [k94].

In the county of Santa Clara **California**, a model was developed in 2008 based on crow deaths as a transmission warning system for human cases of WNV. The initial default parameters predicted 60% of crow deaths with a window of 4–10 days. When parameters were calibrated to match what was actually going on in the field, (mainly in June) the model was 92% accurate. The model showed that transmission was not homogenous for rates or under a particular temperature regime throughout North America [07k].

Mosquitoes from 21 host-feeding species were collected in the states of **New York, New Jersey** and **Tennessee** during the early years of WN fever. From the analysis of their bloodmeals, 24 bird species were hosts. American Robin, Northern Cardinal, Northern Mockingbird, Tufted Titmouse and Brown-headed Cowbird were common hosts. Bloodmeals from American Crows were relatively rare in spite of the crow being near the top of bird abundance in two of the three states according to Breeding Bird Surveys done at times different from when the mosquitoes were collected in the field [a57]. In spite of this methodology, the question was whether WNV was transmitted mainly by mosquitoes, crow-to-crow contact, or a fusion of both?

West Nile virus activity is now being monitored in **Central** and **South American** countries. But there is a possibility of misidentification of WNV for an unrecognized similar virus [02k]. In Europe two new strains of WN-like viruses were found to be serologically WNV, but were genetically different from known strains [b21].

A test was run on 4 species of ixodid ticks to determine if they might be involved in the transmission of WNV [a38]. It was concluded – "Three species of ixodid ticks acquired WNV from viremic hosts and transstadially passed the virus, but vector competency was not determined."

Bird surveys

The Patuxent Wildlife Research Center in Maryland and the Canadian Wildlife Service present the North America Breeding Bird Surveys (BBS) results up to 2010, which includes a decade after the arrival of WNV (**Graph 460**). Along with state and provincial results, the BBS gives results for 134 categories of regions and broad habitat types. Of these, only four have shown a "significant" decrease in American Crow populations – Saskatchewan, West Virginia, The High Plains, and Aspen Parkland. The total number of survey routes in these four areas was 308 (50–132), which indicated a reasonable degree of reliability. **Utah** showed the greatest drop, but methodology has not allowed it to be considered relevant. So far, it seems local populations of crows may be hit hard, but trends for the entire United States and Canada were not obviously on a prolonged decline.

Because crows form large roosts over the winter in parts of the United States and southern Canada, Audubon's Christmas Bird Counts (CBCs), may not be as relevant as BBSs in estimating changes in the numbers of crows. The CBCs (**Graph 460a**) may not be as accurate because [migratory] birds were counted in a location that may differ from where they were exposed to WNV over the breeding season [k67]. CBC data were examined in relation to the impact of WNV on 10 resident

American Crow versus the lazy human mind

bird species in six northeastern states [c18]. For American Crows there were two sets of figures –

(1) a pooling of all annual data from the six states
(2) counting roosts of less than 2,500 crows which will limit the influence of larger roosts containing some migrants

This second restriction resulted in less variance in the annual counts and less of a drop in 2002, the last year included in the analysis. Overall, the data indicated a decline. A paper released in 2004 suggested there was not much consistency among the data from dead crow counts, mosquitoes and the CBC. None of the three can indicate the early stage of a severe local outbreak of WN fever [05h].

WNV was first widely distributed in **California** in 2004. In the Sacramento Valley, road surveys (transects) were used to estimate the regional effect of WNV on local birds, especially two corvids. Comparing the 203 km surveys travelled 30 times in the fall and winter from 1990–'95 (pre-WNV) to those from 2005–'08 (post-WNV), the maximum counts of American Crows declined 63% and Yellow-billed Magpie 83%. The crow declined quickly in 2007 [s95]. Birds in California varied widely in their response to WNV. Using trend analysis in Breeding Bird Survey data from 1980–2003 compared to 2004–'07, and testing birds three other ways, the Rock Dove had a low score and the American Crow had a high score [w68].

Adjusting continental BBS route data on the American Crow for observer differences and missing data, the annual counts showed a steady increase in crow populations from the early 1980s to the year 2000. Then the crow populations began to fall steadily and sometimes dramatically (up to 45%) in local / regional areas in the United States [l05]. Changes in the abundance of the American Crow may further change the dynamics of WNV. One recent line of thought (2005) was crows may amplify the disease because they become generally lethargic and quite viremic for a short period (hours) prior to death. Crows dying from infection were not dead-end hosts. [l03].

In the American northeast, where WNV was first reported, a study found the abundance of crows declined the most in landscapes with reduced forest cover (urban areas), and one year after above-average temperatures in the winter. Warmer winters may support overwinter survival (in sewers) of more mosquitoes with the virus, which leads to an earlier start of WNV in the spring [l05].

WNV killed more crows when –

(1) the initial crow population was high
(2) avian species diversity was low
(3) human populations were high (as in cities)
(4) they were first exposed to the virus during its initial sweep across North America [k95].

In 2009, the first decade of WNV in North American was summarized. All members involved were adjusting and adapting to their new situation. The genetic makeup of the virus was changing to allow for greater replication in vertebrate hosts at higher temperatures. Changing weather and human patterns will provide novel ecological niches to maintain the disease [63b].

Predators

About *Homo sapiens* one crow said, "The most thoughtful, upright animal is also the most pernicious." We do indeed top the list of predators on crows, with our egoism of guns, bombs, poisons, and biased ideas of beauty, morality and usefulness when applied to birds. It's tough being the top predator on the planet. We have to keep thousands of species (including birds) in line by teaching them we are in control. Any action against us on their part will not be tolerated, and will be met with devastating, lethal force.

Hawks and owls

Above and below us, hawks, owls and eagles are the natural predators of the crow. Retaliation by crows usually involves mobbing their winged enemies. But under certain situations, they can live / work together. In **Maryland** in January and February of 1981, two or three American Crows and one or two Red-shouldered Hawks were observed on three different instances feeding together (about 2 m apart) on the ground on scraps of discarded food, and perched close together (about 1 m apart) in an oak tree, all without conflict. A food shortage or cold weather (although no snow on the ground was mentioned) were two possible reasons [185]. I could argue there was no fighting between the two species because of a food surplus. Or crows may sense when a hawk is in a hunting / killing mode and act accordingly.

The rules change when food is very abundant or quite scarce. When Pacific Salmon die by the thousands after spawning, Bald Eagles and crows feed together on the decaying flesh along the bars and shores of coastal rivers. In **Kansas**, severe winter storms caused a Marsh Hawk and 3 crows to eat at once on the carcass of an Eastern Cottontail [165].

A muddy reflection along the Assiniboine River

There are several reports on variable interactions with Cooper's Hawks. The small size (36–51 cm long) of this hawk led to speculation about its ability to kill a crow (45 cm long). But there is a story by Floyd Plasterer who flushed two feeding Cooper's Hawks off a warm carcass of a dead crow in **Pennsylvania**. Plasterer did not observe the kill, but Aaron Bagg witnessed a crow being disabled by a Cooper's Hawk [92s]. A triad of three predators can produce memorable theatre. From **California** Joseph Mailliard watched two Cooper's Hawks, with various techniques, attack a flock of

A tiny portion of the thousands of crows that roost overwinter at Chatham **Ontario** in 2011. Large roosts attract hunters but rarely avian predators

Common Mullein from above

alert crows perched in trees. The hawks were unsuccessful in taking a crow that wintery day. The hawks came to their end, however, when Joseph shot both of them (shooting hawks was a common practice in the early 1900s) m19. In **Washington**, Jesse McGuire saw two crows knock a Cooper's Hawk from a tree to the ground in May. At this point McGuire captured the bird and placed it in a box where it shortly died, probably from shock r55. In **Ohio**, a Cooper's Hawk landed in a tree where crows were perched in July. The crows gave a few short warning notes but showed no overt alarm g34.

A study in **Missouri** of the feeding habits of Cooper's Hawks over two nesting seasons claimed 176 hours of observations divided among 14 nests. Dead birds comprised 87% of species frequency and about 65% of the total weight of all 259 animals brought to the nests. The total bird count was 225 individuals. Two crows (1%) were included in the diet of nestlings t58.

A crow killed a yearling male Cooper's Hawk on 5 May 1985. The attack was observed at 13:45 by Gladys Shafransky of Stevens Point **Wisconsin**. The hawk was being mobbed by American Robins, Blue Jays and 2 American Crows in her backyard. As the hawk was flying, one crow stuck it on the head. The hawk fell to the ground and quickly died. All the other birds grew quiet and flew off. The crows did not feed on the carcass. She donated the hawk to a local museum l68. Near Shippensburg **Pennsylvania**, a dead Cooper's Hawk had the flesh and feathers of a crow in its crop 92s.

If a bird makes a kill, how much can it carry? A 21 gram female House Finch carried 5 grams of nesting material and a 4,170 gram Golden Eagle easily carried a 910 gram load. Based on these two reports, the carrying capacity of birds is about 25% of their own weight 54h.

On a 1,554 km^2 tract west of Laramie **Wyoming**, 55 pairs of Swainson's Hawks nested. The tract also hosted 5 pairs of Red-tailed Hawks, 10 pairs of Ferruginous Hawks, 3 pairs of Golden Eagles, 13 pairs of Marsh Hawks, 39 pairs of Great Horned Owls, and at least 35 pairs of nesting American Crows. Although the incidents of predation were not observed, at least 7 of 10 nests of crows close to nests of Swainson's were destroyed, including large nestlings in two of the crows' nests. Swainson's Hawks may have been involved since several destroyed nests of crows were subsequently lined with green leaves, a characteristic of a Swainson's Hawk's nest-building procedure. A final supposition – "Swainson's nesting success, 22 out of 29 nests, was higher where neither crows or owls nested in the vicinity." In addition to numerous small mammals,

Across North America marauding Cliff Swallows eat young insects

Cooper's Hawks sometimes dine on American Crows. This one is eating a Rock Dove? in the front yard of a home in **Winnipeg** in mid-October

Red-shouldered Hawks sometimes prey on the American Crow. Photograph © Don Baccus, 1999, with permission

some avian prey items of the Swainson's were Western Meadowlarks, Sage Grouse, Horned Larks, ducks, sparrows, blackbirds and crows d70.

During my time in the field, I've never seen a crow being taken by any of its natural predators, other than poetic man. One autumnal morning I watched a Northern Harrier and crows playing together in a series of dives and chases of no consequence. In **Illinois**, eight crows were mobbing a Great Horned Owl. Possibly attracted by the calling, a Northern Harrier flew in and chased away each of the crows. The hawk then left. A few minutes later the owl changed its position, and the crows resumed mobbing it. Surprisingly, the harrier returned, and again routed the crows before leaving the area. When the same crows took after two Short-eared Owls almost an hour later, no harrier came to their rescue 22s.

In **Minnesota**, prey was brought to 13 Northern Goshawk nests over three nesting seasons 2000–'02. About 4,900 hours of video footage showed 652 prey deliveries. Mammals made up 62% of the diet and birds 38%. American Crows (6%) and Ruffed Grouse (5%) were the commonest birds brought to nests 05s. In the Pacific Northwest, **Washington** state in particular, prey remains were noted at 82 nests of Northern Goshawks, *Accipiter gentilis* (length 53–66 cm). From 936 prey items from pellets and food remains, of the 25 birds taken, 3 were crows (species unknown) accounting for less than 1% of the birds recorded w33. In northern **Wisconsin**, nesting Northern Goshawks took Ruffed Grouse (25%), Blue Jay (14%), and American Crows (7%) 34w. In southwestern **New York**, American Crow remains (5%) were near nests of Goshawks and at feeding perches at 10 nest sites. Ruffed Grouse (18%) and Blue Jays (12%) were the two major items of the 8 birds identified g80. In the Upper Peninsula of **Michigan** on 23 July 1955, a Goshawk (1,000 g) approach a flock of 10 American Crows in a tree, then took one (500 g) out of the air to the ground, and flew laboring with the crow's body v20. In **New York** and **Pennsylvania** crows turned up in the Goshawk's menu at 14 nests 73% of the time. Under one nest, 24 crows'